Chapter 8: Lake Okeechobee Watershed Protection Program Annual Update

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SUMMARY

Lake Okeechobee means "big water" in the Seminole Indian language, an appropriate name for a waterbody whose opposite shore cannot be seen from the water's edge. With a surface area of 730 square miles, it is the largest lake in the southeastern United States. Despite its impressive size, the lake is shallow, with an average depth of only 9 feet. Lake Okeechobee and its wetlands are at the center of a much larger watershed, the Greater Everglades, that stretches from the Kissimmee River through the Everglades and finally into Florida Bay. Lake Okeechobee is also a key component of South Florida's water supply and flood control systems. Notably, Lake Okeechobee provides natural habitat for fish, wading birds, and other wildlife, and it supplies essential water for people, farms, and the environment. The lake also provides flood protection, attracts boating and recreation enthusiasts from around the world, and is home to sport and commercial fisheries.

Lake Okeechobee has been subject to three long-term effects: (1) excessive total phosphorus (TP) loads, (2) extreme water level fluctuations, and (3) rapid spread of exotic and nuisance plants in the littoral zone. Despite these influences, Lake Okeechobee continues to be a vital freshwater resource for South Florida, with irreplaceable natural and community values. The South Florida Water Management District (SFWMD or District), Florida Department of Environmental Protection (FDEP), and Florida Department of Agriculture and Consumer Services (FDACS), work cooperatively with the United States Army Corps of Engineers (USACE) and other federal agencies, the Florida Fish and Wildlife Conservation Commission (FWC), local governments, and other stakeholders to address these interconnected issues in order to rehabilitate the lake and enhance the ecosystem and the services it provides, while maintaining other societal functions such as water supply and flood control.

For more than three decades, restoration efforts have been under way to improve the water quality and hydrology of the Lake Okeechobee Watershed (LOW) through implementation of a suite of projects and programs. The nutrient reductions due to the dairy buyout, FDEP dairy

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technology-based rule, the 1989 Lake Okeechobee Works of the District (WOD) Rule [Chapter 40E-61, Florida Administrative Code (F.A.C.)] and other early initiatives made positive impact for the first several years, but leveled-off in the 1990s. As a result, in 2000, the Florida legislature passed the Lake Okeechobee Protection Act (LOPA), which requires the coordinating agencies—the District, FDACS, and FDEP—to work together to reduce TP loading and control exotic species. The LOPA was amended in 2007 to expand restoration efforts to include the St. Lucie and Caloosahatchee River Watersheds, and is now called the Northern Everglades and Estuaries Protection Program (NEEPP) [Section 373.4595, Florida Statutes (F.S.)]. The Lake Okeechobee Watershed Protection Plan (LOWPP) is required under the NEEPP, which promotes a comprehensive, interconnected watershed approach to protecting the lake and its downstream estuaries—Caloosahatchee and St. Lucie. It is a cooperative effort between the District, FDEP, and FDACS.

The NEEPP requires annual progress reports and three-year evaluations of the LOWPP. This chapter of the *2016 South Florida Environmental Report* (SFER) – *Volume I* fulfills the Water Year 2015 (WY2015) (May 1, 2014–April 30, 2015) annual reporting requirements of the NEEPP for the LOWPP. It includes updates on coordinating agency projects being implemented to help address water quality and quantity issues affecting Lake Okeechobee, hydrology and water quality conditions in the lake and its watershed, and lake ecology as required by Subsection 373.4595(6), F.S[3]. Chapter 4 of this volume provides an update on the District's 40E-61 – Regulatory Nutrient Source Control Program (WOD) for the LOW. Further information on the Kissimmee Chain of Lakes and the Kissimmee River and nonindigenous species status in South Florida is presented in Chapters 9 and 7 of this volume, respectively.

WATERSHED UPDATE

A summary of watershed activities and findings is presented below:

- Numerous efforts were conducted under the LOW Construction Project during the WY2015 reporting period:
  - In December 2014, FDEP adopted the Lake Okeechobee Basin Management Action Plan (BMAP), which focuses on the six subwatersheds north of the lake. It builds upon the decade plus work already completed under the LOWPP. Developed collaboratively with existing and new stakeholders, the BMAP works in combination with regulatory programs and provides for an enforceable framework necessary to achieve restoration.
  - Operation (year two) of the Lakeside Ranch Stormwater Treatment Area (STA) Phase I continued. This STA removed a total of 23 metric tons (mt) of TP and 48 mt of TN since its operation on July 3, 2013, through June 30, 2015. This provided about 11.5 mt of TP removal per year, well exceeding its planned design rate of 9 mt per year for Phase I. The USACE permit for Phase II construction was also obtained in July 2015.
  - Operation of the pilot-scale STA in Taylor Creek continued. Based on measured data from 2008 through 2015, an average annual load reduction of approximately 1.2 mt of TP and 4.1 mt of TN was achieved, respectively.
  - Repair of the pilot-scale STA in Nubbin Slough was completed and operations of the facility have been transferred to the District. Once water levels and desirable vegetation have been established, start-up and permit required monitoring will begin.

[3] In accordance with Subsection 373.4595(6), F.S. (Annual Progress Report), the Northern Everglades Fiscal Year 2014-2015 (October 1, 2014–September 30, 2015) expenditures and Northern Everglades Annual Work Plan for Fiscal Year 2014-2015 are included in Appendices 1-5 and 1-6 of this volume, respectively.

- o The District began operations of the Nicodemus Slough storage facility in January, 2015. The District has successfully utilized the site to store water and also provided water supply to the river and local agriculture. Six additional contracts under the Northern Everglades Payment for Environmental Services (NE-PES) were executed in WY2015 as a result of additional legislative funding.
- o The last major phase of the Kissimmee River Restoration Project (KRRP) is under way. Reach 3 backfilling was awarded in Fiscal Year 2014-2015 (October 1, 2014–September 30, 2015) and is currently in progress. The final phase of KRRP construction, Reach 2 backfilling, will be awarded in Fiscal Year 2015-2016 and is planned for completion in 2019–2020.
- o Expansion and operation of hybrid wetland treatment technology (HWTT) continued. HWTT represents a combination of chemical and wetland treatment technologies to remove TP at subbasin and farm scales and the expansion and operation of the Floating Aquatic Vegetative Tilling Project.

- Ten research, modeling, and assessment projects were initiated, continued and/or completed in WY2015. The competed activity includes the nutrient budget analysis for contributing basins to Lake Cypress, Lake Hatchineha, and Lake Kissimmee in the Upper Kissimmee Subwatershed.
- In WY2015, the surface water flow to Lake Okeechobee was 2.863 million ac-ft, or about 3,530 million m^3, which is only 1.2 percent higher than the WY2014 value of 2.828 million ac-ft, or about 3,487 million m^3. However, both TP and total nitrogen (TN) loads to the lake declined despite total discharge to the lake being nearly the same as WY2014. TP loads to the lake from tributaries and atmospheric deposition totaled 450 mt in WY2015, which was 26 percent (159 mt) less than the previous water year of 609 mt of TP. This year's load reduction could be attributed to water discharging to the lake with a lower flow-weighted mean (FWM) concentration of 117 parts per billion [ppb or micrograms per liter (μg/L)] (compared to 165 ppb in WY2014), and partially due to regional activities being implemented to lower TP loading to the lake. The sources of a majority of this water with lower TP concentrations were the Upper and Lower Kissimmee subwatersheds.
- The current five-year (WY2011–WY2015) average TP load from all drainage basins was 436 mt, which exceed the lake's total maximum daily load (TMDL) by 296 mt. This five-year average includes one regional drought that lasted from December 2010 to October 2011.
- The highest subwatershed unit area load of TP comes from the Taylor Creek/Nubbin Slough Subwatershed [0.86 pounds per acre (lbs/ac), or 0.96 kilograms per hectare (kg/ha)], followed by the Indian Prairie Subwatershed (0.71 lbs/ac, or 0.80 kg/ha) and the Lower Kissimmee Subwatershed (0.33 lbs/ac, or 0.37 kg/ha). In terms of FWM TP concentrations, the Taylor Creek/Nubbin Slough Subwatershed was the highest (373 ppb), followed by the Indian Prairie Subwatershed (212 ppb), the combined East, West, and South subwatersheds (210 ppb), and the Fisheating Creek Subwatershed (173 ppb).
- In-lake TP concentrations declined from a high of 233 ppb in WY2005 to 93 ppb in WY2012. In WY2015, the in-lake TP concentration was 134 ppb, which is a 12 percent increase as compared to the WY2014 value of 118 ppb. The current five-year moving (WY2011–WY2015) average TP concentration is 117 ppb, which is within the pre-hurricane (pre-2004) range.
- In WY2015, the TN load to the lake from all drainage basins and atmospheric deposition was 6,191 mt, which is 559 mt less than last year. The unit area load of TN averaged 1.4 lbs/ac (1.6 kg/ha) for the LOW. The highest unit area load came from the Indian Prairie

Subwatershed (6.6 lbs/ac or 7.4 kg/ha), followed by the Lake Istokpoga Subwatershed (4.6 lbs/ac or 5.2 kg/ha), and the Taylor Creek/Nubbin Slough Subwatershed (4.2 lbs/ac or 4.7 kg/ha). In terms of FWM TN concentrations from subwatersheds, the combined East, West, and South Lake Okeechobee subwatersheds had the highest value (2.3 ppm), followed by the Indian Prairie Subwatershed (1.95 ppm), and the Taylor Creek/Nubbin Slough Subwatershed (1.8 ppm).

- Lake Okeechobee water levels were at an elevation of 13.05 feet [ft or 3.98 meters (m)] National Geodetic Vertical Datum of 1929 (NGVD29) on May 1, 2014, which placed water levels in the Base Flow Lake Management Sub-Band. Regulatory releases from the lake to its downstream estuaries were made throughout the water year based on SFWMD adaptive protocols. Pulse releases occurred from mid-July to mid-September 2014 and from mid-October 2014 through the end of April 2015. These discharges were primarily to the Caloosahatchee River, followed by the St. Lucie Estuary. Releases were also made south through the S-351, S-352, and S-354 structures. WY2015 lake stage was at a minimum level of 12.38 ft (3.77 m) NGVD29 on June 12, 2014, and increased to a maximum of 16.01 ft (4.88 m) NGVD29 on October 23, 2014. Water levels ended on April 30, 2015, at a stage of 13.87 ft (4.23 m) NGVD29. Detailed information on regional WY2015 hydrology is presented in Chapter 2 of this volume.

ECOLOGY UPDATE

Submerged aquatic vegetation (SAV) in Lake Okeechobee decreased again slightly, for the third year in a row, to a total coverage of 31,877 acres [ac or 12,900 hectares (ha)] as compared to 33,854 ac (13,700 ha) the previous year. Coverage by the macroalgae *Chara* spp. increased compared to the previous year. However, nearly 1,000 ac (approximately 405 ha) of pondweed (*Potamogeton* spp.), a highly valued vascular species, was identified in the southern region of the lake after being largely absent since the hurricane years of the mid-2000s, Vascular SAV accounted for 67 percent of the total SAV acreage. Despite the continued small declines in measured SAV acreage, the lake appears to be maintaining a healthy SAV community, and winter and spring sentinel sampling indicate the continued persistence of healthy beds at many locations. The trend of SAV being replaced by spike rush (*Eleocharis* spp.) and other emergent aquatic vegetation (EAV) in previously open water nearshore areas, especially in the southern bays, appears to be continuing.

Based on results from sentinel EAV sites, generally drier marsh conditions are resulting in a continued net increase in cattail (*Typha* spp.) acreage, especially in the inner marsh (although there was some cattail loss along the nearshore edge due to somewhat higher lake stages coupled with wind and wave activity). A number of exotic invasive species, including torpedograss (*Panicum repens*) and exotic water grass (*Luziola subintegra*) also appear to be gaining ground as a result of the generally lower lake levels, especially since limited funding has been available for ongoing control efforts. It is unclear what these shifts in the areal coverage of EAV, vascular SAV, and non-vascular SAV are having on habitat values in the littoral and nearshore zones of Lake Okeechobee, although conditions are substantially better than they were during the generally higher lake stages that characterized the mid to late 1990s, or in the years immediately following the 2004 and 2005 hurricanes.

Algal bloom activity and associated microcystin concentrations increased again somewhat in WY2015 as compared to WY2013 and WY2014, although they remain well below the levels encountered immediately following the hurricane years of the mid-2000s. Satellite imagery is now regularly being used to assess bloom conditions on the lake, and good coincidence has been found with routine monthly grab samples, although the development of a Lake Okeechobee-specific algorithm relating spectral imagery to chlorophyll *a* (Chla) concentrations is still being developed.

The Lake Okeechobee fishery continues to be in good condition, and both nearshore and pelagic zone sport fish and forage fish populations appear to be stable. Overall, values for most species remain comparable to historic levels. The black crappie (*Pomoxis nigromaculatus*) population, whose recovery has lagged relative to other important lake species, appears to be stable with continued good population values and size class distribution.

Wading bird utilization of the lake for foraging declined for the third year in a row. The lowest foraging numbers encountered since surveys began in 2010 were recorded in December 2014. Although foraging use increased in succeeding months, a reversal in lake stage (higher stage) in late April 2015, ended the lake's use as foraging habitat for the duration of the breeding season. Nevertheless, it appears that there was sufficient foraging habitat available in surrounding wetlands for the lake's breeding colonies to be somewhat successful in producing fledglings. [Note: Full nesting results for the lake will not be available until the final publication of the annual South Florida Wading Bird Report in December 2015.] This year also marked the first time in recent history that a roseate spoonbill (*Platalea ajaja*) pair successfully fledged chicks in a Lake Okeechobee rookery.

INTRODUCTION

Lake Okeechobee (located at 27º North latitude and 81º West longitude) has a surface area of 445,560 ac [1,800 square kilometers (km^2)], and is extremely shallow with a mean depth of 9 ft (2.7 m) and maximal depth of 12.1 ft (3.7 m) for the past 10 years. The lake is a central part of the interconnected South Florida aquatic ecosystem and the USACE regional flood control project. Lake Okeechobee provides numerous services to diverse users with tremendous economic interest in its health and fate. The lake is the primary water supply for the Okeechobee Utility Authority and the backup water supply for much of South Florida. It supports multimillion-dollar sport and commercial fisheries, and various recreational activities. It also provides habitat for migratory waterfowl, wading birds, alligators (*Alligator mississippiensis*), and the snail kite (*Rostrhamus sociabilis plumbeus*) (Aumen 1995). The lake is also used for flood control during the wet season (June–October) and water supply during the dry season (November–May). The lake faces three major environmental challenges: (1) excessive TP loads, (2) extreme water level fluctuations, and (3) the rapid spread of exotic and nuisance plants.

Lake Okeechobee receives water from a 3.45-million ac (1.4-million ha) watershed that includes four distinct tributary systems: Kissimmee River Valley, Lake Istokpoga–Indian Prairie/Harney Pond, Fisheating Creek, and Taylor Creek/Nubbin Slough (**Figure 8-1**). With the exception of Fisheating Creek, all major inflows to Lake Okeechobee are controlled by gravity-fed or pump-driven water control structures. These four major tributary systems are generally bound by the drainage divides of the major waterbodies and are further divisible into 61 drainage basins and grouped by nine subwatersheds based on hydrology and geography.

The nine subwatersheds comprising the LOW are the Upper Kissimmee (above structure S-65), Lower Kissimmee (between structures S-65E and S-65), Taylor Creek/Nubbin Slough (S-191, S-133, S-135, S-154, and S-154C basins), Lake Istokpoga (above structure S-68), Indian Prairie (C-40, C-41AN, C-41AS, C-41N, C41S, L-48, L-49, L-59E, L-59W, L-60E, L-60W, L-61E, and S-131 basins), Fisheating Creek (Fisheating Creek, L-61W, and Nicodemus Slough North basins), East Lake Okeechobee (Basin 8, C-44, S-153, and L-8 basins), West Lake Okeechobee (East Caloosahatchee, Hicpochee North, and Nicodemus Slough South), and South Lake Okeechobee, which includes the S-4 Basin, and most basins in the Everglades Agricultural Area (EAA), as well as Chapter 298, F.S., Districts (**Figure 8-1**).

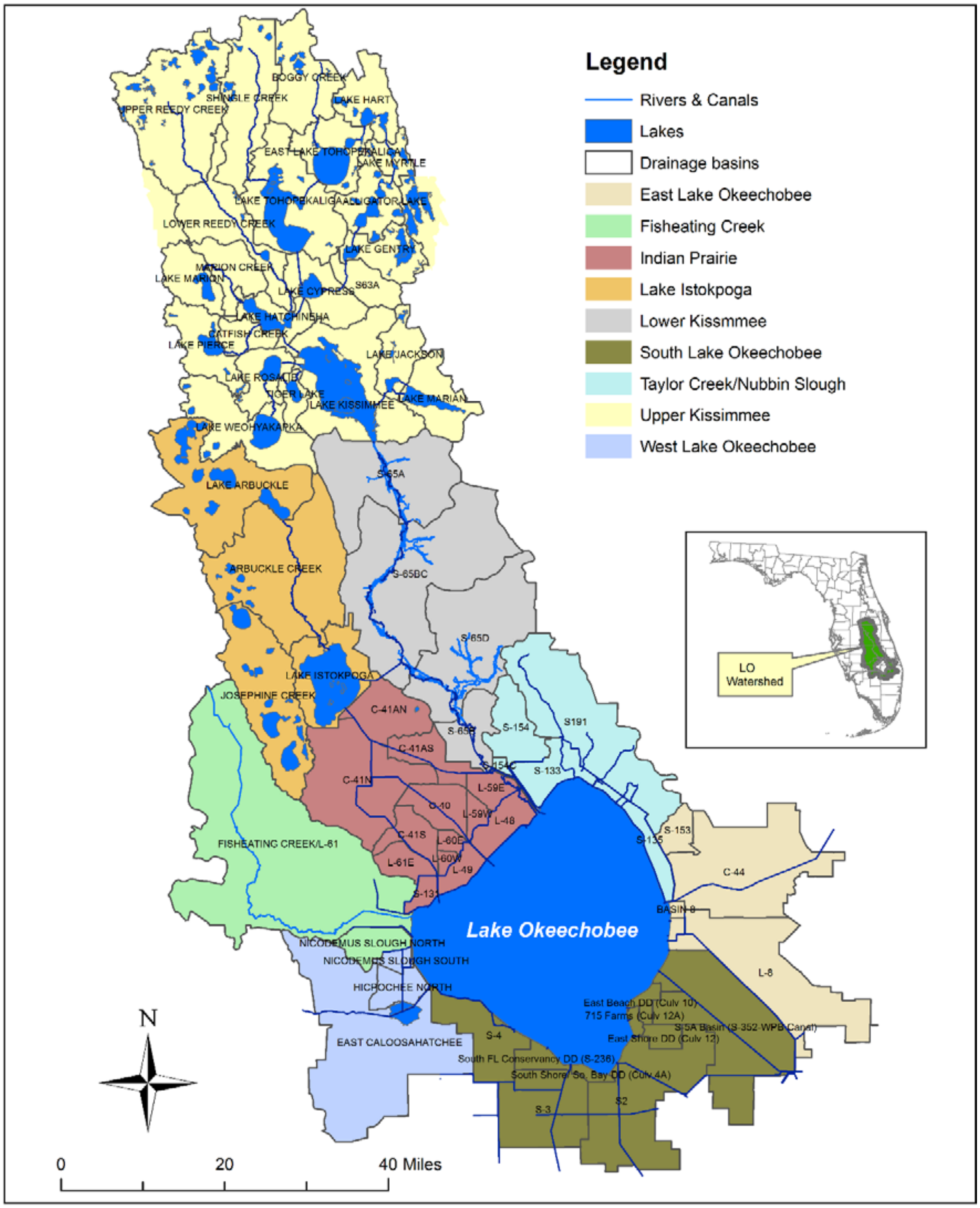


Figure 8-1. LOW detailing subwatersheds, drainage basins, and major hydrology (black labels indicate basins).

The Upper Kissimmee, Lower Kissimmee, Taylor Creek/Nubbin Slough, Lake Istokpoga, Indian Prairie, and Fisheating Creek subwatersheds primarily drain into Lake Okeechobee by gravity. The S-133 Basin (part of the Taylor Creek/Nubbin Slough Subwatershed) and other urban areas can also pump water into the lake from the north. When high lake stages make gravity flows impossible, urban areas north of the lake are drained via pumps. The Eastern and Western Lake Okeechobee subwatersheds contribute flow by gravity, but only when Lake Okeechobee water levels are below 14.5 and 11.5 ft (4.4 and 3.5 m), respectively, in relation to NGVD29.

Land uses shown in **Figure 8-2** are part of a 2009 land use data set to which modification to the dairy land uses were made in January 2013 as part of the Nutrient Budget Tool (PN-Budget) Upgrade and Calibration Project (JGH Engineering 2013). As some of the LOW area lies within the St. Johns River and Southwest Florida water management districts (SJRWMD and SWFWMD, respectively), the land use data set was created by merging the SWFWMD 2009, SJRWMD 2009, and SFWMD 2008/2009 Florida Land Cover Classification System (FLUCCS) land use data sets and then clipping these to the study area.

Agricultural land use accounts for 51 percent of the LOW total area (1.75 million ac or 706,000 ha); followed by natural areas including wetlands, upland forests, and waterbodies (31 percent). Urban areas comprise approximately 10 percent of the land use. The majority of agricultural land uses are improved pasture (20 percent), followed by unimproved/woodland pasture (9 percent) for beef cattle grazing north of the lake. Sugarcane production is primarily south of the lake within the EAA and citrus groves are located primarily within the East Lake Okeechobee and Lake Istokpoga subwatersheds. Sod farms, row crops, dairies, and other agriculture make up the remaining land uses within the watershed. Further information on detailed land use breakdown is presented in the 2014 LOWPP Update (Bertolotti et al. 2014).

For the East Lake Okeechobee Subwatershed, the major land use is agriculture, followed by wetland, upland forest, and urban land uses. The Fisheating Creek and the West Lake Okeechobee subwatersheds are dominated by agricultural land uses, followed by wetland and upland forest. The Indian Prairie and Lower Kissimmee subwatersheds are dominated by agricultural land uses, followed by wetland and rangeland. For Lake Istokpoga and the Upper Kissimmee Subwatershed, the major land use is agriculture, followed by wetland and urban land uses. The South Lake Okeechobee Subwatershed and Taylor Creek/Nubbin Slough Subwatershed are dominated by agricultural land uses, followed by urban, wetland, and water.

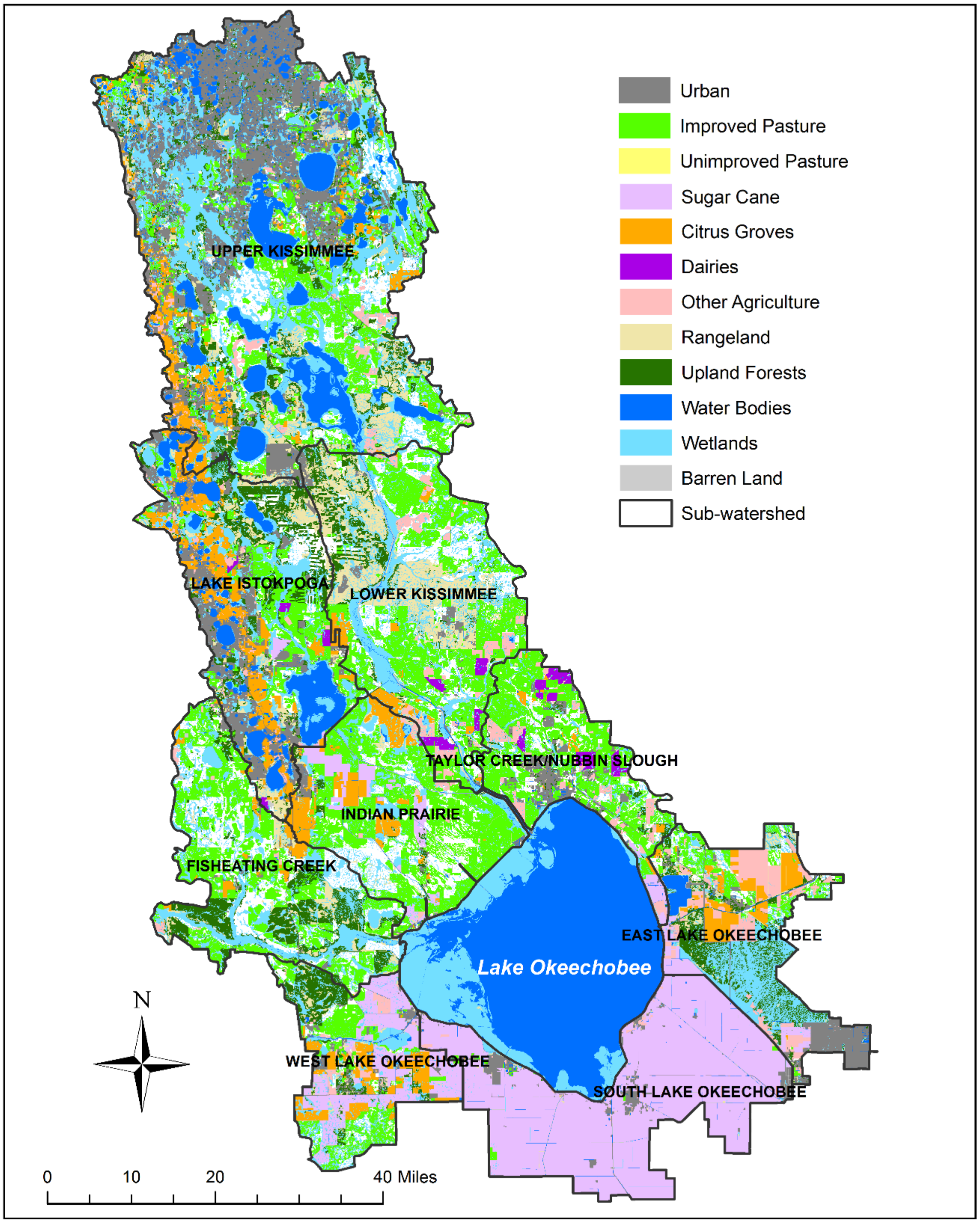


Figure 8-2. Land use distribution detailing Florida FLUCCS level III for agriculture and level I for other land use types in the LOW.

OVERVIEW OF THE LAKE OKEECHOBEE WATERSHED PROTECTION PROGRAM

Passed in 2000, the LOPA (Section 373.4595, F.S.) established a restoration and protection program for the lake. In 2007, the Florida legislature amended the LOPA and is now known as the NEEPP. The NEEPP promotes a comprehensive, interconnected watershed approach to protect Lake Okeechobee and the Caloosahatchee and St. Lucie rivers and their watersheds (SFWMD et al. 2008). The NEEPP includes the Lake Okeechobee, the Caloosahatchee River, and the St. Lucie River watershed protection programs. The protection plans developed pursuant to NEEPP for each of these three Northern Everglades watersheds identify actions (e.g., programs and projects) to help in achieving water quality and quantity objectives for the watersheds and to restore habitat. Water quality objectives are based on TMDLs established by FDEP. The TMDL for Lake Okeechobee is 140 mt of TP per year, which consists of 105 mt of TP per year from the watershed tributaries and 35 mt per year from atmospheric deposition. Storage targets are aimed at achieving appropriate water levels in Lake Okeechobee and more desirable salinities within the estuaries.

The District, in cooperation with FDEP and FDACS, collectively known as the coordinating agencies, developed the Lake Okeechobee Protection Plan, which is reevaluated every three years pursuant to the NEEPP. The Lake Okeechobee Protection Plan was originally submitted to the Florida legislature on January 1, 2004 (SFWMD et al. 2004), the Lake Okeechobee Phase II Technical Plan (LOP2TP) was submitted to the Florida legislature in February 2008 (SFWMD et al. 2008), and three year evaluations to the LOWPP were completed in 2011 and 2014 as required by the NEEPP (SFWMD et al. 2011, Bertolotti et al. 2014).

The coordinating agencies are jointly responsible for implementing the NEEPP, each with specific areas of responsibility. FDEP's BMAPs in the Northern Everglades serve as the overarching water quality restoration plans. Other major responsibilities of the coordinating agencies include implementation of urban and agricultural source control programs, identification and implementation of water quality and quantity projects, and reporting and maintaining a monitoring network. SFWMD, in cooperation with FDEP and FDACS, is the lead agency for annual status reports and three-year updates to the LOWPP; however, each agency is responsible for implementing its respective programs.

The NEEPP requires the District to submit an annual progress report to the Florida legislature. This chapter fulfills the annual progress report requirement of the NEEPP for the LOW and constitutes the fifteenth annual progress report summarizing the hydrology, water quality, and aquatic habitat conditions of the lake and its watershed based on the results of research and water quality monitoring, as well as the status of the Lake Okeechobee Watershed Construction Project (LOWCP). The annual progress reports for the St. Lucie and Caloosahatchee River watersheds are provided in Chapter 10 of this volume. More details on exotics within the District boundaries and source control programs under WOD permits for surrounding watersheds are presented in Chapters 7 and 4 of this volume, respectively. In accordance with Subsection 373.4595(6), F.S., the Northern Everglades Fiscal Year 2014-2015 (October 1, 2014–September 30, 2015) expenditures and Northern Everglades Annual Work Plan for Fiscal Year 2014-2015 are included in Appendices 1-5 and 1-6 of this volume, respectively.

The LOWPP is a major component of the NEEP and includes three main components: (1) the LOW Phosphorus Control Program; (2) the LOWCP, which includes the Phase I and Phase II Technical Plans; and (3) the LOW Research and Water Quality Monitoring Program (**Figure 8-3**). A brief description of these elements is provided below. In addition, the LOWPP includes the Lake Okeechobee Exotic Species Control Program and Lake Okeechobee Internal Phosphorus Management Program. Further information on these programs is presented in the 2014 LOWPP Update (Bertolotti et al. 2014).

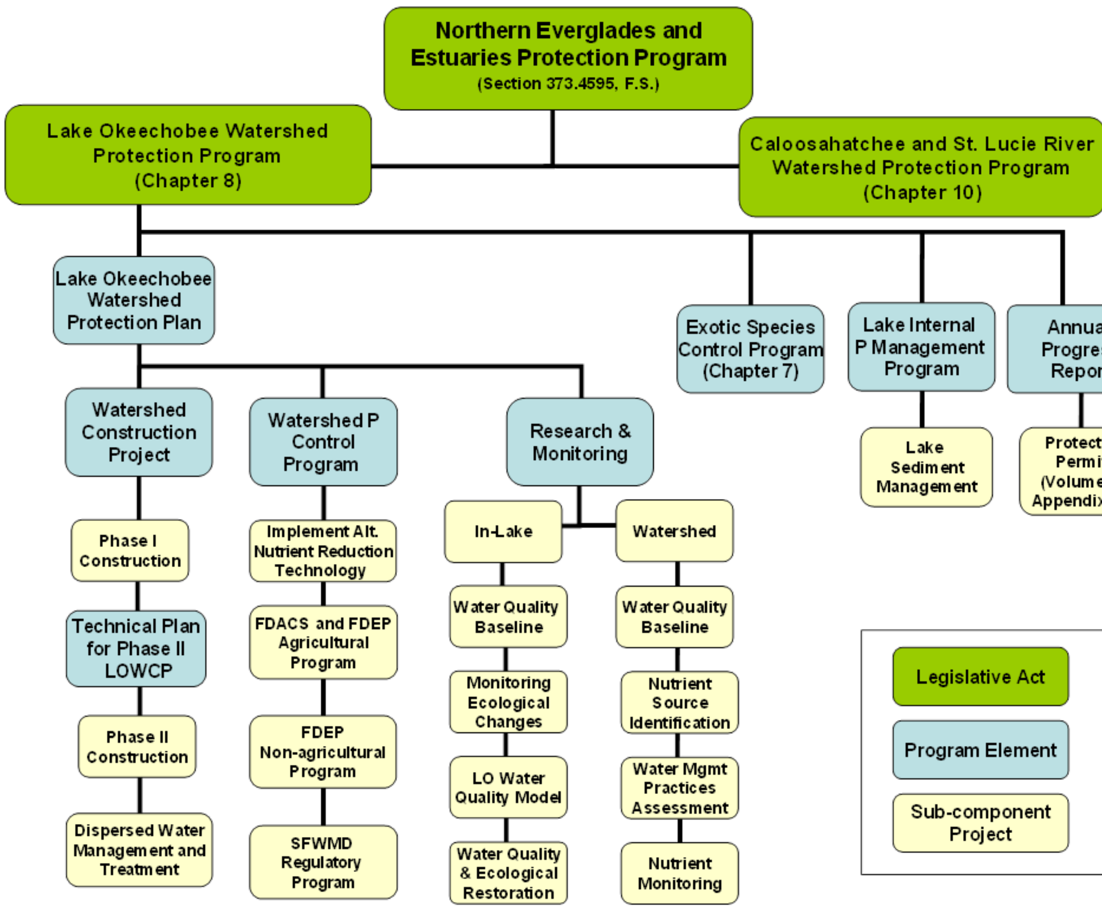


Figure 8-3. NEEPP structure, detailing the LOWPP elements and projects. [Note: Alt. – Alternate; LO – Lake Okeechobee; and P – phosphorus.]

The LOW Phosphorus Control Program is a multifaceted program that includes (1) continued implementation of regulatory and incentive-based agricultural and nonagricultural best management practices (BMPs); (2) development and implementation of improved BMPs; (3) improvement and restoration of hydrologic function of natural and managed systems; and (4) use of alternative technologies for nutrient reduction. The District, FDEP, and FDACS cooperatively implement this program through an interagency agreement in coordination with existing regulatory programs, including the Lake Okeechobee Works of the District Permitting Program (Chapter 40E-61, F.A.C.), FDEP Dairy Rule (Chapter 62-670.500, F.A.C.), and Everglades Forever Act (Section 373.4592, F.S.).

According to the NEEPP, the multifaceted approach to reducing TP loads by improving the management of phosphorus sources within the watershed includes implementation of existing regulations and BMPs and development and implementation of improved BMPs. For example, WOD permits are issued under Chapters 40E-61 and 40E-63, F.A.C., which are longstanding regulations that establish criteria to ensure discharges from agricultural and nonagricultural sources meet legislative objectives for water quality protection. The District continues to implement the delegated Environmental Resource Permitting (ERP) Program and mandated Lake Okeechobee WOD nutrient source control program, which are described in Chapter 4 of this volume. The District also collects water quality monitoring data at sites identified as key locations for tracking progress toward achieving water quality goals and identifying water quality concerns and potential areas for BMP improvement. The NEEPP requires FDACS to implement an incentive-based BMP program on agricultural lands within the LOW. FDEP implements the ERP Program and other urban BMP programs and rules. More details about the LOW Phosphorus Control Program are provided in the 2014 LOWPP Update (Bertolotti et al. 2014). Works of the District source control activities for WY2015 and anticipated WY2016 activities are presented in Chapter 4 of this volume.

The LOWCP identifies water quality and storage projects to improve hydrology, water quality, and aquatic habitats within the watershed. For a detailed description of the LOWCP and the associated activities see the 2014 LOWPP Update (Bertolotti et al. 2014). Updates on the LOWCP activities are provided under the *Watershed Construction Project Update and Related Activities* section of this chapter.

The District in cooperation with the other coordinating agencies developed a research and water quality monitoring program, as required by NEEPP. The plan includes a flow, water quality, and ecological monitoring network. The data from this network is used to assess progress towards achieving goals and to monitor the ecological health of the system. It also includes projects aimed towards improving our understanding of the system. Results from the monitoring and updates on research and water quality monitoring program are provided in this chapter. Results from the Lake Okeechobee Watershed Assessment Monitoring (LOWA) network, which was developed as part of the regulatory WOD source control program, are presented in Appendix 4-3 of this volume.

WATERSHED CONSTRUCTION PROJECT UPDATE AND RELATED ACTIVITIES

Addressing the complex and varying problems in the LOW requires a multifaceted restoration approach. The coordinating agencies are committed to restoring Lake Okeechobee and its watershed, continuing existing efforts, and identifying new opportunities to improve the ecosystem. Over the past four years, the coordinating agencies have implemented various projects to improve conditions including continued operation of the Lakeside Ranch STA Phase I, continued operation of a pilot-scale STA in Taylor Creek, expansion of the Dispersed Water Management Program, continued effort on the KRRP, and implementation and expansion of HWTT and floating aquatic vegetative tilling (FAVT) technologies to remove nutrients at subbasin and farm scales (**Table 8-1**). This section provides updates to the LOWCP and related activities during WY2015. SFWMD is continuing to coordinate with USACE on the KRRP and more details on this coordination effort can be found in Chapter 9. The status of the C-44 Reservoir/STA Project is reported in the *Construction Project Updates* section in Chapter 10 of this volume.

Table 8-1. General description and status of LOWCP during WY2015.

Project Name (Investigator)	Sub-Watershed	General Description	Size/Capacity	Estimated Water Quality and Quantity Benefits	Year Construction Started and Completed or Expected Completion Date	WY2015 Status Update
Lakeside Ranch Stormwater Treatment Area (SFWMD)	Taylor Creek/ Nubbin Slough	This project, expedited under the NEEPP, is located on 2,700 ac (1,090 ha) lands in western Martin County adjacent to Lake Okeechobee. The project is designed in two phases: the Phase I northern STA and inflow pump station; and the Phase II southern STA, including a second pump station to manage rim canal levels in Lake Okeechobee during high water flow periods and potentially to recirculate the water in Lake Okeechobee back to the STA for additional phosphorus removal.	The northern STA has an effective treatment area of 919 ac (372 ha) and the pump's capacity is at 250 cubic feet per second [cfs or 7 cubic meters per second (m^3/sec)]. The southern STA has an effective treatment area of 788 ac (319 ha).	The design document estimated an average annual load reduction of 19 metric tons per year (mt/yr), with 9 mt/yr from Phase I and 10 mt/yr from Phase II. The overall TP removal efficiency was designed at 43 percent.	Under Phase I, the northern STA started in 2009 and S-650 pump station started in 2010. Both were completed in 2012. Under Phase II, construction of the southern STA is planned to start in Fiscal Year 2015-2016. The construction of S-191A pump station is contingent on funding.	During WY2015, Lakeside Ranch STA captured 30,851 ac-ft of stormwater runoff from the S-191 Basin. The STA removed 13.9 mt of TP out of 16.3 mt it received in WY2015 (an 85 percent reduction in TP loads). The STA also removed 31 mt of TN out of 70 mt it received in WY2015 (a 44 percent reduction in TN loads). Overall, a total of 23 mt of TP has been removed in the past two years (from July 2013 to June 2015), well exceeding the designed rate of 9 mt per year. The STA also has removed 48 mt of TN during the same two-year period.
Taylor Creek Stormwater Treatment Area (SFWMD)	Taylor Creek/ Nubbin Slough	This project is located on the District-owned Grassy Island Ranch along the banks of Taylor Creek. This project is part of the Lake Okeechobee Critical Restoration Project, which was authorized through the federal Water Resources Development Act of 1996. USACE was responsible for the design and construction of the STA and SFWMD is responsible for operations and maintenance.	The site is 142 ac (57 ha) with an effective treatment area of 118 acres (48 ha). This two-celled STA in series is expected to treat about 10 percent of the water flow in Taylor Creek.	The design document (Stanley Consultants, Inc. 2003) estimated an average annual load reduction of 2.1 mt of TP. The overall TP removal efficiency was designed for 38 percent.	Started in 2006 and completed in 2008	The STA retained 1.16 mt of TP out of 2.09 mt it received in WY2015, for a TP load reduction of over 55 percent. As of April 30, 2015, the STA has had 60 months of flow-through operation. During this period, the STA treated 46,433 ac-ft of runoff water and removed 5.84 mt of TP, resulting in an annual load reduction of approximately 1.2 mt of TP. The STA removed 5.7 mt of TN out of 12.8 mt it received in WY2015 (a 45 percent reduction). As of April 30, 2015, the average annual load reduction of TN was approximately 4.1 mt.

Table 8-1. Continued.

Project Name (Investigator)	Sub-Watershed	General Description	Size/Capacity	Estimated Water Quality and Quantity Benefits	Year Construction Started and Completed or Expected Completion Date	WY2015 Status Update
Nubbin Slough Stormwater Treatment Area (SFWMD)	Taylor Creek/ Nubbin Slough	This STA is located on District-owned lands at the New Palm Dairy site along the banks of Nubbin Slough. This project is part of the Lake Okeechobee Critical Restoration Project, which was authorized through the federal Water Resources Development Act of 1996. USACE was responsible for the design and construction of the STA and the SFWMD is responsible for operations and maintenance.	This two-celled STA is 809 ac (327 ha) with an effective treatment area of 773 ac (313 ha).	The projected long-term average TP reduction within the STA is approximately 5 mt/yr (Stanley Consultants, Inc. 2003)	Started in 2005 and completed in 2006	The Nubbin Slough STA Project was transferred to the District by USACE on March 18, 2015. Start-up monitoring is currently under way. Once the start-up monitoring requirement for TP reduction is achieved, then flow-through operation will begin.
Dispersed Water Management (DWM) Program (SFWMD)	Northern Everglades	The goals and objectives of the DWM Program are to provide shallow water storage to enhance Lake Okeechobee and estuary health by reducing runoff and discharge volumes, reducing nutrient loading to downstream receiving waters, and expanding groundwater recharge opportunities. The four main categories of projects under the DWM Program include storage and retention projects on private lands, storage and retention projects on public lands, NE-PES projects on ranch lands, and Water Farming Payment for Environmental Services (WF-PES) pilot projects on fallow citrus lands.	The individual project storage benefits for operational projects range from 24 acre-feet per year [ac-ft/yr or 29,592 cubic meters per year (m^3/yr)] to 33,860 ac-ft/yr (41.75 million m^3/yr).	The total storage benefit created by the 39 completed and operational projects through WY2015 is approximately 85,258 ac-ft/yr (105.2 million m^3/yr). This includes contributions from other agencies and landowners.	The program started in 2005 and is ongoing.	Six additional NE PES-2 contracts were executed in WY2015 as a result of additional legislative funding. Nicodemus Slough began operations in January 2015. This storage facility has approximately 24,000 ac-ft (29.59 million m^3) of static storage at the design stage.

Table 8-1. Continued.

Project Name (Investigator)	Sub-Watershed	General Description	Size/Capacity	Estimated Water Quality and Quantity Benefits	Year Construction Started and Completed or Expected Completion Date	WY2015 Status Update
Kissimmee River Restoration Project (SFWMD)	Lower Kissimmee	The main goal of KRRP is to restore ecological integrity to approximately one-third of the river and its floodplain that existed before the river was channelized in the 1960s. The project involves acquiring more than 102,000 ac (41,280 ha) of land in the river's floodplain and headwaters, backfilling 22 miles [35 kilometers (km)] of the C-38 canal, reconnecting remnant sections of the original river channel, removing two water control structures, modifying portions of the river's headwaters, and implementation of the Headwaters Regulation Schedule to meet the project hydrologic criteria needed to meet KRRP ecological goals. More detail on KRRP is available in Chapter 9 of this volume.	The first three construction phases reestablished flow to 24 miles (39 km) of river channel and allowed intermittent inundation of 15,041 ac (6,089 ha) of floodplain.	TP load reduction estimates ranged from 20.6 mt/yr (LOP2TP; SFWMD et al. 2008) to 17.75 mt/yr (FDEP Lake Okeechobee BMAP; FDEP et al. 2014).	The first three construction phases of restoration were completed between 2001 and 2009. The last major phases of construction are under way and are currently scheduled for completion in 2019.	The last major phase of the KRRP is under way. Reach 3 backfilling was awarded in Fiscal Year 2014-2015 and is currently in progress; the final phase of KRRP construction, Reach 2 backfilling, will be awarded in Fiscal Year 2015-2016 and is planned for completion in 2019–2020.
Hybrid Wetland Treatment Technology (FDACS)	Taylor Creek and Nubbin Slough Subwater-shed and St. Lucie River Watershed.	The HWTT technology combines attributes of treatment wetlands and chemical treatment systems. There are currently six operational HWTT systems and one under permitting in the Northern Everglades; five in the LOW (Nubbin Slough, Mosquito Creek, Lemkin Creek, Grassy Island and Wolff Ditch) and two in the St. Lucie River Watershed (Ideal 2 Grove and Bessey Creek).	Ideal 2 Grove 1.3 cfs (0.04 m^3/sec), Nubbin Slough 7.4 cfs (0.21 m^3/sec), Mosquito Creek 6 cfs (0.17 m^3/sec), Lemkin Creek 5 cfs (0.14 m^3/sec), Wolff Ditch 20 cfs (0.57 m^3/sec), Grassy Island in the Taylor Creek Basin 30 cfs (0.85 m^3/sec) Bessey Creek 20 cfs (0.57 m^3/sec).	FWM TP concentration reductions of the seven active HWTT facilities during the entire study period ranged from 67 to 93 percent.	Ideal 2 Grove, Nubbin Slough, and Mosquito Creek were constructed in WY2008. Lemkin Creek and Wolff Ditch were deployed in WY2011. Grassy Island was constructed in WY2012 with final expansion in WY2014. Bessey Creek was constructed in 2015.	Danforth Creek, which drains into the St. Lucie River, will operate at a peak flow of 25 cfs (0.71 m^3/sec). It is under construction and will be completed by March 2016.

Table 8-1. Continued.

Project Name (Investigator)	Sub-Watershed	General Description	Size/Capacity	Estimated Water Quality and Quantity Benefits	Year Construction Started and Completed or Expected Completion Date	WY2015 Status Update
Floating Aquatic Vegetative Tilling (FDACS)	Fisheating Creek and West Lake Okeechobee	FAVT systems are operated with an initial growing season during which the floating aquatic vegetation (FAV) assimilate nutrients and grow to a high density. The FAVT is then drained during the dry season, thereby stranding the FAV on the soil. After a natural drying process, the plant material is tilled into the soil, stored in deeper zones, and used to repopulate the wetland for the subsequent growth period. The technology uses the direct assimilation of nutrients from the water column through the use of floating plant roots (as compared to plants rooted in the soil), and all of the biomass is rapidly incorporated directly into the soil through tilling. The FAVT process may result in a reduction of up to 80 percent of land needed for treatment as compared to traditional wetland treatment systems.	The East Caloosahatchee FAVT site is 540 acres (219 ha) and has a capacity of 90 cfs (2.55 m^3/sec). It is designed to treat local agricultural runoff from the Hendry Hilliard Water Control District, the East Caloosahatchee River, and Lake Okeechobee. The Fisheating Creek facility is comprised of 100 acres (40 ha) of FAV and 200 acres (81 ha) of managed dispersed flow area and will have a treatment capacity of 120 cfs (3.4 m^3/sec).	16.2 mt from the Fisheating Creek FAVT. The East Caloosahatchee FAVT facility is anticipated to remove approximately 6 mt of TP.	The East Caloosahatchee facility was completed in June 2014. The Fisheating Creek facility has an expected completion date in 2016.	The East Caloosahatchee FAVT project is operational. Legislative funding has been appropriated for a FAVT site to treat water from the Fisheating Creek Subwatershed.

A key component to achieving water quality goals in the Northern Everglades are FDEP's BMAPs, which serve as the overarching water quality restoration plans. A BMAP is the "blueprint" for restoring impaired waters by reducing pollutant loadings to meet a TMDL. It represents a comprehensive set of strategies—permit limits on wastewater facilities, urban and agricultural BMPs, conservation programs, financial assistance and revenue generating activities, etc.—designed to implement the nutrient load reductions established by the TMDLs. In December 2014, FDEP adopted the Lake Okeechobee BMAP, which focuses on the six subwatersheds north of the lake. It builds upon the decade plus work already completed under the LOWPP. Developed collaboratively with existing and new stakeholders, it works in combination with the regulatory programs and provides for an enforceable framework necessary to achieve restoration. These actions, coupled with the LOWPP, make for a comprehensive suite of actions to address Lake Okeechobee restoration.

Phase I of the Lake Okeechobee BMAP is currently being implemented and expected to reduce TP loading to the lake by 145 to 148 mt per year. FDEP continues to work with stakeholders and coordinating agencies through BMAP implementation to track progress toward achieving goals, identify the projects necessary to achieve the TMDLs, and estimate project nutrient reduction benefits. The first semiannual Lake Okeechobee BMAP meeting was held on July 1, 2015.

DISPERSED WATER MANAGEMENT PROJECTS IN THE NORTHERN EVERGLADES

The legislative intent of the NEEPP includes encouraging and supporting the development of creative partnerships to facilitate or further the restoration of surface water resources in the LOW and the St. Lucie and Caloosahatchee river watersheds. One way this is being accomplished is through the Dispersed Water Management (DWM) Program. The goals and objectives of the DWM Program are to provide shallow water storage, retention, and detention to enhance Lake Okeechobee and estuary health by reducing discharge volumes, reducing nutrient loading to downstream receiving waters, and expanding groundwater recharge opportunities.

The DWM Program is a multifaceted approach to working cooperatively with public and private land owners to identify, plan, and implement mechanisms to retain or store water. The four main categories of projects under the District's DWM Program include storage and retention projects on public lands, storage and retention projects on private lands, NE-PES projects, and Water Farming Payment for Environmental Services (WF-PES) pilot projects. The storage, retention, and detention created by the 39 completed and operational projects within the DWM Program through WY2015 is approximately 85,000 ac-ft. This includes contributions from the United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS) Wetland Reserve Program (WRP) and other programs, the FDACS BMP Program, agricultural landowners, agricultural organizations, non-governmental organizations, and local governments.

A map of the projects is shown in **Figure 8-4.** The comprehensive list of the District's DWM projects in the Northern Everglades and their current status and estimated benefits, as of June 2015, is shown in **Table 8-2**. The District administers the DWM Program in consultation with FDEP, FDACS, and USDA NRCS.

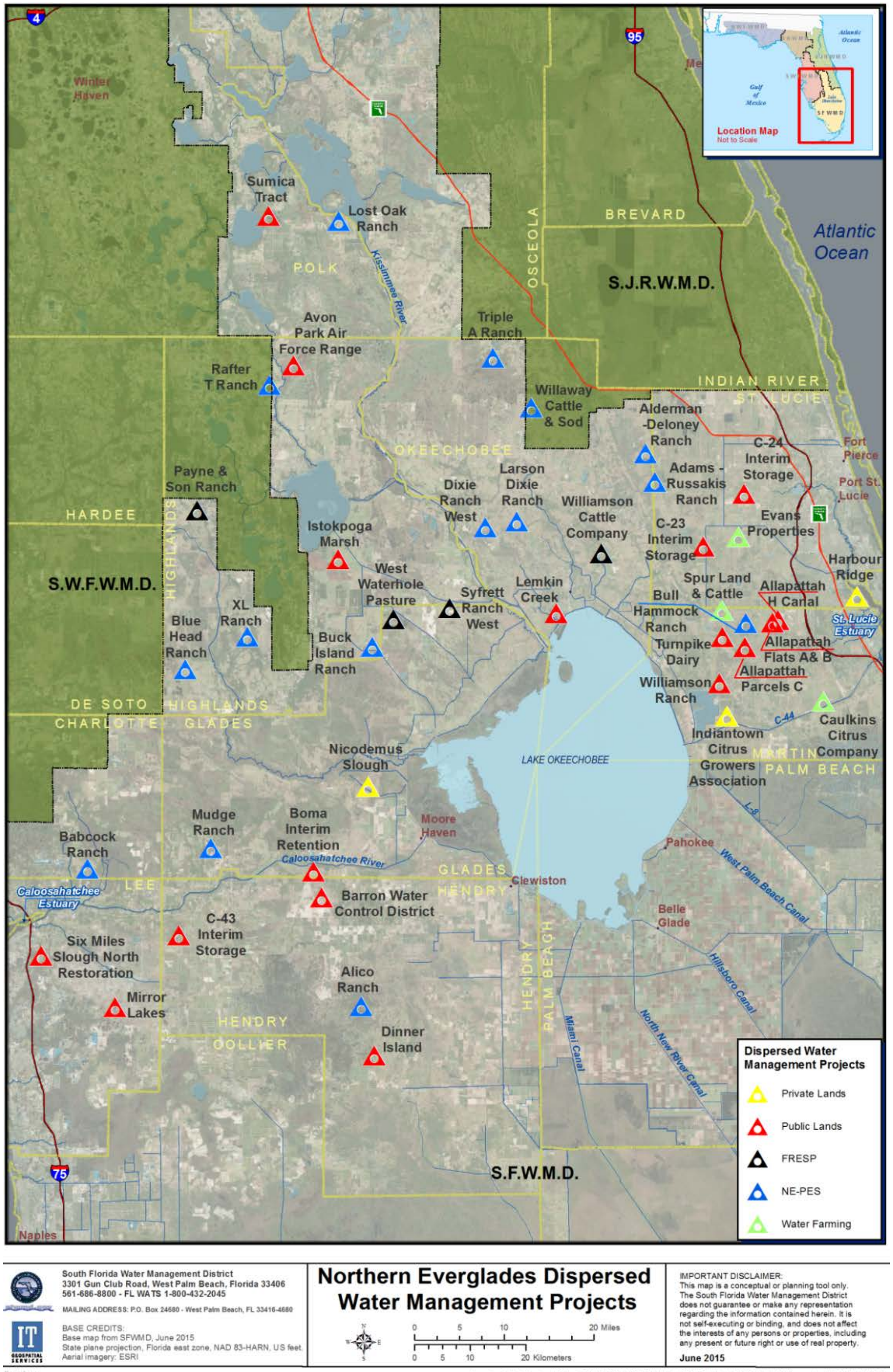


Figure 8-4. DWM projects located in the Northern Everglades. Projects include water storage on private and public lands, NE-PES, Florida Ranchlands Environmental Services Projects (FRESP), and water farming.

Table 8-2. Comprehensive list of SFWMD's DWM projects located in the Northern Everglades and their status and estimated storage benefits in acre-feet per year (ac-ft/yr). [Note: Gov – government.]

Project Name	Watershed	Drainage Basin	Category	Status	Estimated Storage Benefits (ac-ft/yr)
Lykes West Waterhole	Lake Okeechobee	C-41N, C-40	FRESP	Operation & Maintenance	4,848
Buck Island Ranch (NE PES-1)	Lake Okeechobee	C-41N	NE-PES 1	Operation & Maintenance	1,573
XL Ranch	Lake Okeechobee	Fisheating Creek/L-61	NE-PES 1	Operation & Maintenance	887
Lost Oak Ranch (aka Shady Oaks Ranch)	Lake Okeechobee	Lake Kissimmee	NE-PES 1	Operation & Maintenance	374
Dixie Ranch	Lake Okeechobee	S-154	NE-PES 1	Operation & Maintenance	856
Triple A Ranch	Lake Okeechobee	S-65BC	NE-PES 1	Operation & Maintenance	397
Willaway Cattle and Sod	Lake Okeechobee	S-65D	NE-PES 1	Operation & Maintenance	229
Dixie West	Lake Okeechobee	S-65E	NE-PES 1	Operation & Maintenance	315
Rafter T Ranch WMA (NE PES-2)	Lake Okeechobee	Arbuckle Creek	NE-PES 2	Operation & Maintenance	1,298
Buck Island Ranch WMA (NE PES-2)	Lake Okeechobee	C-41N	NE-PES 2	Construction	620
Bluehead Ranch	Lake Okeechobee	Fisheating Creek/L-61	NE-PES 2	Design/Permitting	3,462
Buck Island Ranch A, B and C	Lake Okeechobee	C-41N	WRP	Operation & Maintenance	62
Payne and Son Ranch	Lake Okeechobee	Fisheating Creek/L-61	WRP	Operation & Maintenance	932
Francis Creek	Lake Okeechobee	Fisheating Creek/L-61	WRP	Operation & Maintenance	47
Mary's Creek	Lake Okeechobee	Fisheating Creek/L-61	WRP	Operation & Maintenance	208
Boney Ranch Wetland Reserve	Lake Okeechobee	Fisheating Creek/L-61	WRP	Operation & Maintenance	300
Lake Wales Ridge State Forest	Lake Okeechobee	Lake Istokpoga	WRP	Operation & Maintenance	220
Williamson Cattle Company	Lake Okeechobee	S191	WRP	Operation & Maintenance	150
Lazy O Ranch	Lake Okeechobee	S-65E, S-154	WRP	Operation & Maintenance	250
Nicodemus Slough	Lake Okeechobee	Nicodemus Slough North	Other	Operation & Maintenance	33,860
Lemkin Creek	Lake Okeechobee	S-133	District Lands	Planning	
Avon Park Airforce Range	Lake Okeechobee	Arbuckle Creek	Other Gov Lands	Operation & Maintenance	10,000
Istokpoga Marsh	Lake Okeechobee	C-41N	Other Gov Lands	Design/Permitting	950
Sumica Tract	Lake Okeechobee	Lake Weohyakapka, Tiger Lake	Other Gov Lands	Operation & Maintenance	281
Subtotal Lake Okeechobee Watershed					***62,119***

Table 8-2. Continued.

Project Name	Watershed	Drainage Basin	Category	Status	Estimated Storage Benefits (ac-ft/yr)
Alderman-Deloney Ranch	St. Lucie	C-25	NE-PES 1	Operation & Maintenance	147
Bull Hammock Ranch, LTD WMA	St. Lucie	C-23	NE-PES 2	Operation & Maintenance	228
Adams - Russakis Ranch WMA	St. Lucie	C-24	NE-PES 2	Design/Permitting	508
Spur Land & Cattle / Bull Hammock Ranch	St. Lucie	C-23	Water Farming	Operation & Maintenance	870
Evans Properties (Alt. E-1)	St. Lucie	C-24	Water Farming	Operation & Maintenance	3,635
Caulkins	St. Lucie	C-44	Water Farming	Operation & Maintenance	6,780
Winding Waters Natural Area	St. Lucie	C-17	WRP	Operation & Maintenance	46
Williamson Ranch/Turnpike Dairy	St. Lucie	C-23	WRP	Operation & Maintenance	547
Allapattah Parcels A and B - Phase I	St. Lucie	C-23	WRP	Design/Permitting	3,500
Allapattah Parcels A and B - Phase II	St. Lucie	C-23	WRP	Design/Permitting	1,243
Allapattah H Canal	St. Lucie	C-23	WRP	Operation & Maintenance	1,610
Pal-Mar East	St. Lucie	Grove	WRP	Operation & Maintenance	2,000
Audubon Loop	St. Lucie	South Mid- Estuary	WRP	Operation & Maintenance	24
Indiantown Citrus Growers Phase I and II	St. Lucie	C-44	Other	Operation & Maintenance	3,550
Harbour Ridge	St. Lucie	St. Lucie North Fork	Other	Operation & Maintenance	667
Allapattah Parcel C	St. Lucie	C-23	District Lands	Design/Permitting	
C-23 Interim Storage (Section D - PC55)	St. Lucie	C-23, C-24	District Lands	Construction	110
C-23 Interim Storage (Section C)	St. Lucie	C-23, C-24	District Lands	Construction	212
Adams Ranch Cattle and Citrus Operations (ARCCO) (C-23/C-24 Complex)	St. Lucie	C-24	District Lands	Operation & Maintenance	190
C-24 Interim	St. Lucie	C-24	District Lands	Planning	
Subtotal St. Lucie River Watershed					***25,867***

Table 8-2. Continued.

Project Name	Watershed	Drainage Basin	Category	Status	Estimated Storage Benefits (ac-ft/yr)
Alico Ranch WMA	Caloosahatchee	East Caloosahatchee, Okaloacoochee, C-139	NE-PES 2	Design/Permitting	91,944
Babcock Ranch WMA	Caloosahatchee	Tidal North	NE-PES 2	Design/Permitting	1,214
Mudge Ranch	Caloosahatchee	West Caloosahatchee	NE-PES 2	Operation & Maintenance	396
Spirit of the Wild Management Area	Caloosahatchee	West Caloosahatchee	WRP	Operation & Maintenance	615
BOMA	Caloosahatchee	East Caloosahatchee	District Lands	Operation & Maintenance	836
Barron Water Control District	Caloosahatchee	East Caloosahatchee	Other Gov Lands	Operation & Maintenance	5,000
ECWCD Mirror Lakes/Halfway Pond Phase I	Caloosahatchee	Tidal South	Other Gov Lands	Operation & Maintenance	1,000
ECWCD Mirror Lakes/Halfway Pond Phase II	Caloosahatchee	Tidal South	Other Gov Lands	Planning	500
ECWCD Mirror Lakes/Halfway Pond Phase III	Caloosahatchee	Tidal South	Other Gov Lands	Planning	2,000
Six Mile Cypress Slough North	Caloosahatchee	Tidal South	Other Gov Lands	Construction	1,400
Subtotal Caloosahatchee River Watershed					***104,905***
Dinner Island Ranch	Everglades	C-139	WRP	Operation & Maintenance	30
Subtotal Everglades					***30***
Total for Northern Everglades					***192,921***

Storage and Retention Projects on Public Lands

Projects on public land enhance Lake Okeechobee and estuary health by reducing discharge volumes and nutrient loading to downstream receiving waters through modifications to existing water management structures and implementing operational strategies. In many cases, storage, retention, and detention are obtained by increasing the discharge control elevation of on-site drainage facilities or impounding water in shallow retention and detention areas. These projects are typically conducted on non-District lands where the District provides cost-share funding to other public entities to implement a water management improvement project or on District lands where the District identifies lands that may be available for interim water storage projects while a regional project is being planned, designed, or authorized for construction. Previous analysis of District lands have identified available parcels for interim projects that are currently being used for storage or are in the planning/design phases. The District is conducting an updated review of available District lands for additional interim project sites beginning with the C-23 and C-24 drainage basins. This review is anticipated to be completed in Fiscal Year 2015-2016.

Storage and Retention Projects on Private Lands

Similar to public lands, projects on private land also enhance Lake Okeechobee and estuary health by reducing discharge volumes and nutrient loading to downstream receiving waters through modifications to existing water management structures and implementing operational strategies. In many cases, storage, retention, and detention are obtained through execution of cooperative cost-share agreements that maximize the benefits the project can provide. These projects typically have exceptional circumstances such as offering large, cost-effective benefits to the regional system, aiding local or regional water resource-related issues, or benefiting multiple watersheds.

Northern Everglades Payment for Environmental Services

As the basis for the NE-PES Program, the Florida Ranchlands Environmental Services Pilot (FRESP) Project was a five-year pilot project to field-test and develop a payment for environmental services program. FRESP partners included eight ranchers, the World Wildlife Fund, the Florida Cattlemen's Association, FDACS, FDEP, the University of Florida Institute of Food and Agricultural Sciences, USDA NRCS, the MacArthur Agro-ecology Research Center, and SFWMD. Further details of the FRESP Program are provided in Section 5 of the 2011 LOWPP Update (SFWMD et al. 2011).

An example of a very successful FRESP project that has continued operation through an extended agreement is the West Waterhole Pasture Project. It is a 2,370-acre marsh located in Glades County that drains into the C-40 (Indian Prairie) Basin. The project's goal is to remove nutrients from on-site water (citrus grove) and regional water from the C-40 canal by pumping canal water into the marsh before these waters discharges back to the C-40 canal. In 2014, a total of 6.8 billion gallons of water was pumped into the marsh. Twenty-four percent of the total inflow volume was retained in the marsh. Monitoring data indicates that 10.3 mt of TP (88 percent of the total inflow) was retained in the marsh. Also, 48.7 mt of TN (56 percent of the total inflow) was retained in the marsh in 2014.

The coordinating agencies have expanded opportunities for DWM in the Northern Everglades watersheds whereby private landowners manage water on parts of their property to provide two different water management services: water retention/storage or nutrient (TP or TN) load reduction through the District's NE-PES Program. Solicitations released through this program allow for an innovative approach by offering eligible cattle ranchers the opportunity to compete for contracts for water and nutrient retention. The goal of the NE-PES Program is to establish relationships via contracts with private landowners to obtain the water management services of water retention and nutrient retention to reduce flows and nutrient loads to Lake Okeechobee and the estuaries from the watersheds. The NE-PES is a working program that keeps ranchers working and reduces pressure to convert ranchlands to development or other more intense agricultural uses. The District is responsible for administering this program in coordination with FDACS, FDEP, and USDA NRCS.

The first NE-PES solicitation was released in January 2011 offering eligible cattle ranchers the opportunity to compete for contracts for water and nutrient retention. Eight water retention contracts were awarded as a result of that solicitation. All eight projects are operational. The total estimated retention is 4,778 ac-ft. The second NE-PES solicitation was released in December 2012. Nineteen submittals were received and as a result eight contracts were awarded and are in various stages of implementation. NE-PES projects will be operated as long as funding is available for up to 10 years, as stated in the contracts.

Water Farming Payment for Environmental Services Pilot Program

An innovative approach to delivering environmental services, similar to NE-PES, is the WF-PES pilot program. This concept seeks to field test the potential for retaining water on fallow citrus lands. Two feasibility analyses were completed: one in April 2012 by the Indian River Citrus League, and one in October 2013 by the Gulf Citrus Growers Association, both under cooperative agreements with the District. The DWM Program WF-PES pilot projects will help determine the cost-effectiveness and benefits associated with retaining water on fallow citrus lands. A WF-PES pilot project request for proposal solicitation for the St. Lucie Estuary watershed area (Martin and St. Lucie counties) closed on June 5, 2013, with five submitted proposals resulting in three executed contracts. This program is partially funded through a Clean Water Act Section 319(h) grant agreement with FDEP. Their estimated combined total storage is 11,285 ac-ft per year. The projects have been constructed and are all in the operational/data collection phase. Upon completion of the pilot, data collected and lessons learned will guide the development of any future WF-PES projects.

WATERSHED MONITORING AND ASSESSMENT

As required by the NEEPP, the District monitors the water quality of inflows to and outflows from Lake Okeechobee at District-operated control structures and maintains a long-term water quality monitoring network within the LOW (**Figure 8-5**). This network is continuously reviewed for efficiency and to ensure all data objectives associated with legislatively mandated and permit required monitoring are being met. This informs stakeholders and the public on the progress of federally and state-funded restoration efforts. In addition, the District coordinates monitoring efforts with FDACS, FDEP, and the United States Geological Survey (USGS) to leverage monitoring sites and reduce duplication of efforts. This information is also leveraged in FDEP's Lake Okeechobee Watershed BMAP (FDEP et al. 2014).

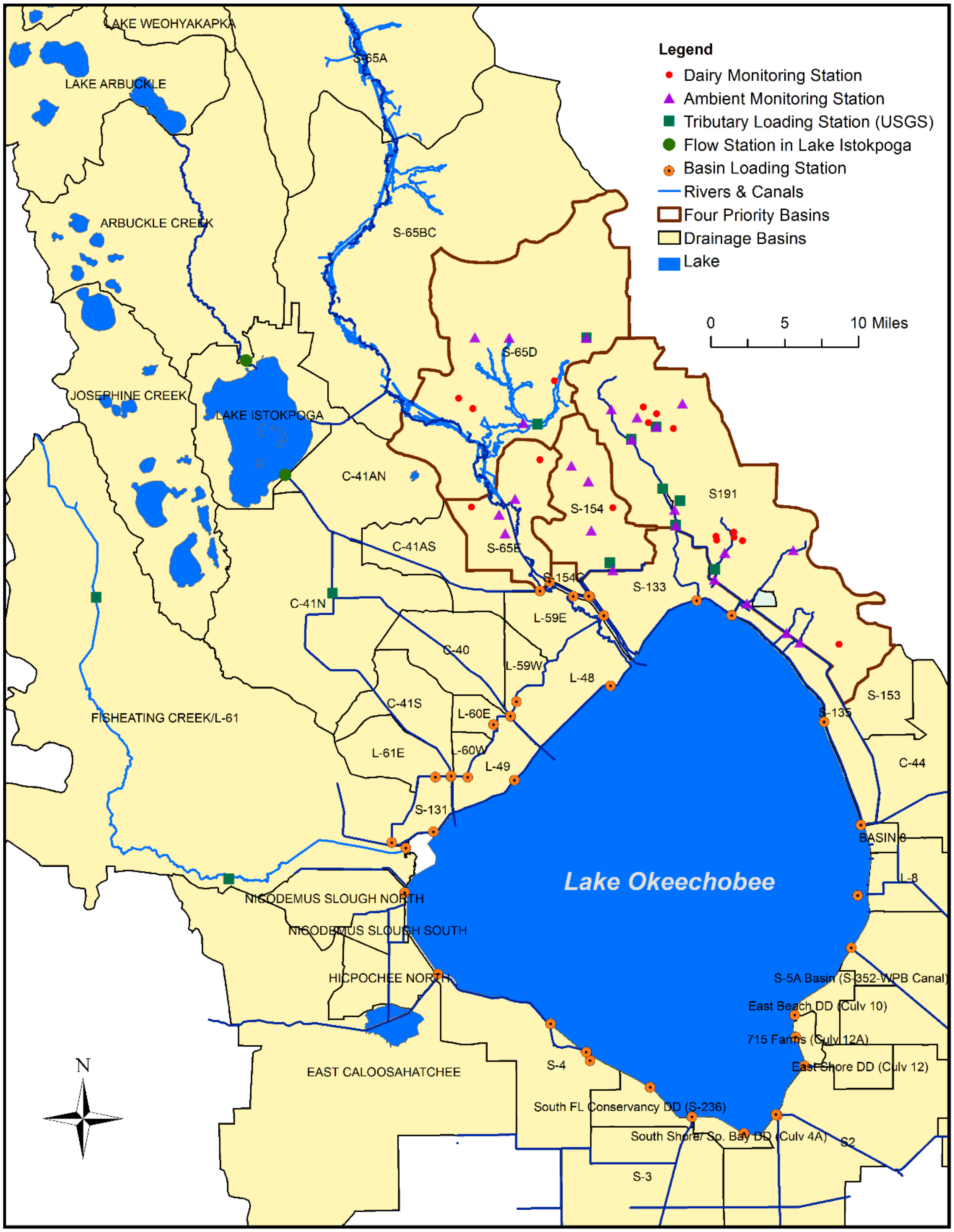


Figure 8-5. Locations of WY2015 water quality sampling stations under the ambient, tributary, and basin loading projects in the LOW.

The District's current monitoring network includes sample locations at three hydrologic levels within the LOW: (1) subwatershed and drainage basin level (basin loading stations), (2) subbasin level (tributary and ambient stations), and (3) project/parcel/farm level (dairy stations). Load monitoring is conducted at stations at the subwatershed and drainage basin level (basin loading stations). Basin loading stations are monitored for TP, TN, and flow. The Lake Okeechobee Operating Permit issued by FDEP requires additional Class I water quality parameters be collected from 34 control structures with direct discharges into Lake Okeechobee. The subbasin-level concentration monitoring is conducted at ambient monitoring stations and tributary stations under three different projects: the ambient long-term trend projects, which are the Kissimmee River Eutrophication Abatement (KREA) and Taylor Creek Nubbins Slough (TCNS) projects and sites formerly part of the subbasin loading project (OKUSGS). The District collects and analyzes water quality from the OKUSGS sites. USGS, under contract from FDACS, maintains flow data from several of these sites. The LOWA Project also monitors TP at the tributary level and is used to support the WOD BMP Program, Chapter 40E-61, F.A.C. (see Chapter 4 and Appendix 4-3 of this volume). The collection of data from project-specific, parcel- or farm-level monitoring (dairy monitoring stations) is the third tier of monitoring conducted under the umbrella of the watershed network. Data from all these monitoring efforts reside in the District's corporate environmental database, DBHYDRO, and are associated with the project names listed above in parentheses.

Total Phosphorus and Total Nitrogen Loads to Lake Okeechobee

TP and TN loading rates into Lake Okeechobee varied over time as a result of a combination of climatic conditions, land use changes, and changes in water management conditions. No extreme climatic conditions were experienced in WY2015. However, when comparing WY2015 and WY2014, there were differences in dry and wet season rainfall patterns in the three major rainfall regions. The three rainfall regions are the Upper Kissimmee, which includes the Upper Kissimmee subwatershed; the Lower Kissimmee, which includes the Lower Kissimmee, Indian Prairie, and Lake Istokpoga subwatersheds; and the Lake Okeechobee rainfall region, which includes the Lake Okeechobee, Fisheating Creek, and Taylor Creek/Nubbin Slough subwatersheds. During the wet season (May to September), there was less rainfall in WY2015 than in WY2014 for all three regions (**Figure 8-6**). This deficit was offset by higher rainfall in the dry season of WY2015 than WY2014. In the Upper Kissimmee region, rainfall in the WY2015 dry season exceeded that of WY2014 by 7 inches (**Figure 8-6**). This extra rainfall along with a falling stage/discharge schedule for Lake Kissimmee from February to June resulted in water releases at S-65 that were 53 percent higher than WY2014. This discharge resulted in an increase of flow from the Kissimmee River to Lake Okeechobee of 26 percent compared to the previous water year.

Despite this increased flow from the Kissimmee River, the total flow from the watershed to the lake was almost the same as in WY2014. This was attributed to drier-than-normal rainfall conditions in the Lower Kissimmee and Lake Okeechobee rainfall regions during the dry season (**Figure 8-6**), resulting in lower flows from watersheds closer to the lake. Further information on rainfall in WY2015 is presented in Appendix 2-1 of this volume.

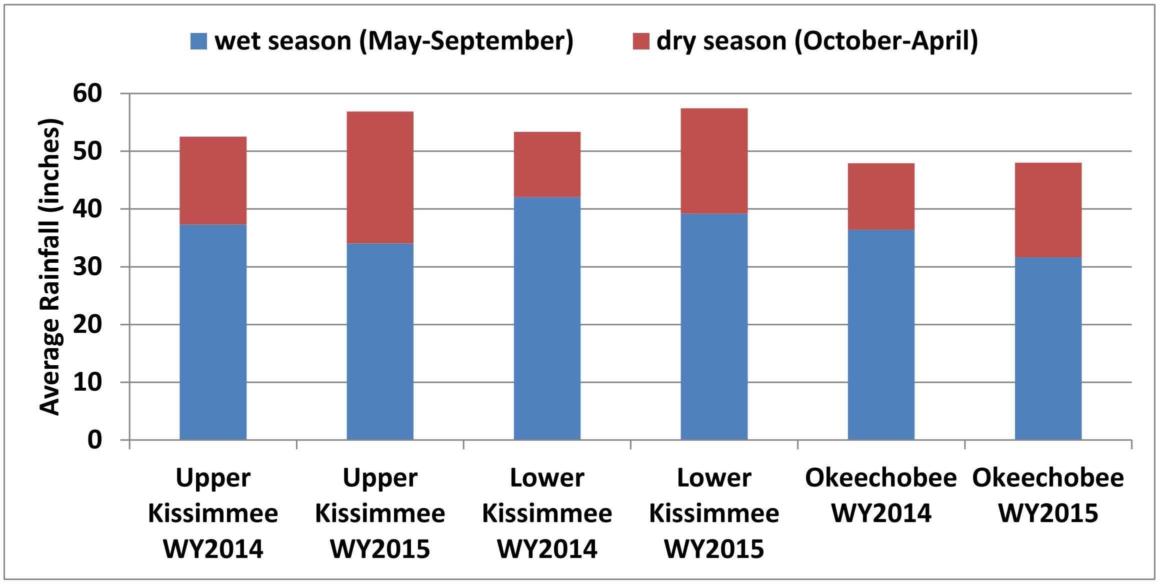


Figure 8-6. Rainfall in the Upper Kissimmee, Lower Kissimmee, and Lake Okeechobee regions in WY2015 and WY2014 by season. The Upper Kissmmee region is the same as the Upper Kissimmee subwatershed. The Lower Kissimmee region includes the Lower Kissimmee, Indian Prairie, and Lake Istokpoga subwatersheds. The Lake Okeechobee region includes Lake Okeechobee, and Fisheating Creek and Taylor Creek/Nubbin Slough subwatersheds.

As shown in **Table 8-3**, TP loads to the lake from tributaries and atmospheric deposition (estimated as 35 mt per year) totaled 450 mt in WY2015. This was 26 percent (159 mt) less than the previous water year despite a 1.2 percent (35,000 ac-ft) increase in inflow to the lake. One of the reasons for the reduction compared to WY2014 is the source of a majority of water was the Upper Chain of Lakes (above S-65), which has relatively lower TP concentrations compared to other subwatersheds north of the lake (63 ppb). In addition, the estimated concentration from the Lower Kissimmee also declined from 157 ppb in WY2014 to 116 ppb in WY2015. TP concentrations from Taylor Creek/Nubbin Slough, Fisheating Creek, and the South Lake Okeechobee subwatersheds decreased from 457, 207, and 245 ppb to 373, 122, and 170 ppb, respectively. These five subwatersheds supplied over 70 percent of total flow to the lake. This exemplifies how the nutrient concentrations in the source water and not only the volume of water can greatly affect loading to the lake.

From WY1981 through WY2015, the highest TP loading rate was 1,189 mt in WY1983, followed by 960 mt in WY2005, and 913 mt in WY1998. The highest five-year average load was 714 mt during the WY2002–WY2006 period of record (mainly due to the high discharges to the lake during and after the 2004 and 2005 hurricanes). The five-year average from WY2007 through WY2011 was the lowest average value since 1981 because it included three of the driest years (WY2007, WY2008, and WY2011) on record. The most recent five-year average load was 436 mt (WY2011–WY2015), which exceed the TMDL by 296 mt. This five-year average includes one regional drought that lasted from December 2010 to October 2011. During this period, flow and load to the lake were reduced substantially compared to a 1991–2005 baseline of 2.54 million ac-ft (31.32 million m^3) and 546 mt TP (James and Zhang 2008).

Table 8-3. Annual TP loads to Lake Okeechobee in metric tons (mt) from WY1981 through WY2015. [Note: NA – not available.]

Water Year (May-April)	Measured TP Load[a] (mt)	Long-Term Load (Five-Year Moving Average)[a] (mt)	Long-Term Over-Target Load (Five-Year Moving Average)[a/b] (mt)
1981	151	NA	NA
1982	440	NA	NA
1983	1,189	NA	NA
1984	369	NA	NA
1985	500	530	390
1986	421	584	444
1987	562	608	468
1988	488	468	328
1989	229	440	300
1990	365	413	273
1991	401	409	269
1992	408	378	238
1993	519	385	245
1994	180	375	235
1995	617	425	285
1996	644	474	334
1997	167	425	285
1998	913	504	364
1999	312	531	391
2000	685	544	404
2001	134	442	302
2002	624	533	393
2003	639	479	339
2004	553	527	387
2005	960	582	442
2006	795	715	575
2007	203	630	490
2008	246	551	411
2009	656	572	432
2010	478	496	356
2011	177	352	212
2012	377	387	247
2013	569	451	311
2014	609	442	302
2015	450	436	296

a. Includes an atmospheric load of 35 metric tons per year (mt/yr) based on the Lake Okeechobee TMDL (FDEP 2001).
b. Target is the Lake Okeechobee TMDL of 140 mt compared to a five-year moving average.

As shown in **Table 8-4**, from WY2000 through WY2015, the highest TN loading rate was 8,775 mt in WY2005, followed by 8,279 mt in WY2003 and 7,992 mt in WY2006. The highest five-year average load was 7,880 mt during the WY2002–WY2006 period of record (mainly due to the high discharges to the lake during and after the 2004 and 2005 hurricanes). The WY2015 TN load was estimated at 6,191 mt, which is a decrease of 559 mt (8 percent) compared to the previous WY2014 load of 6,750 mt. WY2011–WY2015 TN load averaged 5,374 mt, a 27 mt decrease from the WY2010–WY2014 average of 5,401 mt.

Table 8-4. Annual TN loads to Lake Okeechobee from WY2000 through WY2015. [Note: NA – not available.]

Water Year May–April	Measured TN Load[a] (mt)	Long-Term TN Load (Five-Year Moving Average)[a] (mt)
2000	6,693	NA
2001	2,517	NA
2002	7,826	NA
2003	8,279	NA
2004	6,526	6,368
2005	8,775	6,785
2006	7,992	7,880
2007	2,965	6,907
2008	3,393	5,930
2009	6,689	5,963
2010	6,325	5,473
2011	2,913	4,457
2012	4,620	4,788
2013	6,397	5,389
2014	6,750	5,401
2015	6,191	5,374

a. Includes atmospheric load of 1,233 mt/yr to account for atmospheric deposition.

Total Phosphorus and Total Nitrogen Loading Data by Drainage Basin

Surface water flow and TP and TN loads to the lake for WY2015 were calculated for the major drainage basins using the basin loading stations. These calculations include discharges from Lakes Istokpoga and Kissimmee. These lakes are the outfalls of subwatersheds that collect water flow and nutrient loads from smaller surrounding drainage basins (**Figure 8-5**). Data are based on monitoring stations where flow is continuously monitored and TP and TN samples are collected biweekly, based on flow, or monthly at a minimum.

As shown in **Table 8-5**, the TP load to the lake from all drainage basins and atmospheric deposition [estimated at 35 mt (FDEP 2001)] in WY2015 was 450 mt despite total discharge to the lake being nearly the same as WY2014 (within 2 percent). The load reduction is attributed to water discharging to the lake with a lower FWM TP concentration of 117 ppb (**Table 8-5**), a 29 percent decrease compared with WY2014 (165 µg/L) for the Lake Okeechobee Watershed. This is less than the in-lake TP concentration estimate of 134 ppb (discussed in the *Lake Status* section of this chapter). The primary source of this water with a lower TP concentration was the Upper Chain of Lakes (north of S-65), which discharged over 1.171 million ac-ft of water in WY2015 (increase of 53 percent from WY2014). The average FWM TP concentration at S-65 was 63 ppb, which was an 18 percent reduction from the previous year.

The watershed-wide unit area load of TP averaged 0.27 lbs/ac (0.30 kg/ha) in WY2015, a 27 percent decrease comparing with the WY2014 value of 0.37 lbs/ac (0.41 kg/ha). At the drainage basin level, the highest unit area load of TP in WY2015 was from the L-59W basin (4.96 lbs/ac, or 5.56 kg/ha) in the Indian Prairie Subwatershed, followed by the S-154C basin (2.66 lbs/ac, or 2.98 kg/ha) in the Taylor Creek/Nubbin Slough Subwatershed, and the L-60E basin (1.18 lbs/ac, or 1.32 kg/ha) in the Indian Prairie Subwatershed. The S-154C basin had the highest FWM TP concentration value (798 ppb), followed by the S-191 basin (544 ppb) in the Taylor Creek/Nubbin Slough Subwatershed, the C-41 basin (507 ppb), and the C-40 basin (491 ppb) in the Indian Prairie Subwatershed during WY2015.

A summary of data at the subwatershed level is provided in **Table 8-6**. During WY2015, the largest surface water inflow was from the Upper Kissimmee Subwatershed (above structure S-65), followed by the Lower Kissimmee and Indian Prairie subwatersheds. The Upper Kissimmee Subwatershed covers about 30 percent of the drainage area in the Lake Okeechobee Watershed, and contributed approximately 41 percent of total inflow during WY2015. The Lower Kissimmee Subwatershed comprises 12 percent of the drainage area in the Lake Okeechobee Watershed and contributes about 16 percent of total inflow during WY2015. The Indian Prairie Subwatershed covers eight percent of the drainage area in the Lake Okeechobee Watershed and discharges 12 percent of the total inflow in WY2015.

At the subwatershed level, the highest unit area load of TP comes from the Taylor Creek/Nubbin Slough Subwatershed (0.86 lbs/ac or 0.96 kg/ha), followed by the Indian Prairie Subwatershed (0.71 lbs/ac or 0.80 kg/ha) and the Lower Kissimmee Subwatershed (0.33 lbs/ac or 0.37 kg/ha). In terms of FWM TP concentrations, the Taylor Creek/Nubbin Slough Subwatershed had the highest value (373 ppb), followed by the Indian Prairie Subwatershed (212 ppb), and the combined East, West, and South Lake Okeechobee subwatersheds (173 ppb) during WY2015. Unlike the subwatersheds north of the lake, the discharges to the lake from East, West, and South Lake Okeechobee subwatersheds are highly managed based on the hydrologic and human factors. Moreover, the majority of runoff from these subwatersheds is typically directed away from the lake. The highest surface runoff that reached the lake comes from the Indian Prairie Subwatershed [14.9 inches or 37.8 centimeters (cm)], followed by the Upper Kissimmee Subwatershed (13.7 inches or 34.8 cm) and the Lake Istokpoga Subwatershed (13.6 inches or 34.5 cm). The WY2015 average runoff for the watershed was about 10 inches (25.4 cm).

Table 8-5. WY2015 surface water inflows, TP loads and concentrations (µg/L or ppb), and unit area loads in pounds per acre (lb/ac) from the drainage basins to Lake Okeechobee.[a]

Source	Area		Discharge		TP Load		Unit Area Load	Average TP Conc.
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppb)
East Lake Okeechobee Sub-watershed	**239,013**	**6.9**	**71,412**	**2.5**	**15.4**	**3.7**	**0.14**	**175**
C-44/S-153/Basin 8 (S-308 at St. Lucie Canal)	132,572	3.8	16,876	0.6	3.6	0.9	0.06	173
L-8 Basin (Culvert 10A)	106,440	3.1	54,536	1.9	11.8	2.8	0.24	175
Fisheating Creek Sub-watershed	**318,042**	**9.2**	**180,291**	**6.3**	**27.2**	**6.6**	**0.19**	**122**
Fisheating Creek at Lakeport/L-61W Basin	298,713	8.7	170,574	6.0	26.5	6.4	0.20	126
Nicodemus Slough North (Culvert 5)	19,329	0.6	9,717	0.3	0.7	0.2	0.09	63
Indian Prairie Sub-watershed	**276,577**	**8.0**	**342,374**	**12.0**	**89.5**	**21.6**	**0.71**	**212**
C-40 Basin [(S-72) – (S-68)]	24,076	0.7	10,407	0.4	6.3	1.5	0.58	491
C-41 Basin [(S-71) – (S-68)]	112,880	3.3	45,409	1.6	28.4	6.8	0.55	507
C-41A Basin [(S-84) – (S-68)]	57,748	1.7	151,475	5.3	25.7	6.2	0.98	137
L-48 Basin (S-127 total)	20,798	0.6	19,261	0.7	4.6	1.1	0.49	193
L-49 Basin (S-129 total)	11,966	0.3	8,595	0.3	0.4	0.1	0.08	40
L-59E Basin [(G-33)+(G-34)]	12,589	0.4	5,491	0.2	0.7	0.2	0.11	97
L-59W Basin (G-74)	6,596	0.2	46,357	1.6	14.8	3.6	4.96	259
L-60E Basin (G-75)	4,944	0.1	12,042	0.4	2.6	0.6	1.18	178
L-60W Basin (G-76)	3,453	0.1	2,531	0.1	0.4	0.1	0.24	121
L-61E Basin	14,407	0.4	31,709	1.1	4.5	1.1	0.69	116
S-131 Basin	7,122	0.2	9,096	0.3	1.0	0.2	0.32	92
Taylor Creek/Nubbin Slough Sub-watershed	**197,795**	**5.7**	**167,617**	**5.9**	**77.0**	**18.6**	**0.86**	**373**
S-133 Basin	25,626	0.7	33,451	1.2	8.2	2.0	0.71	200
S-135 Basin	17,756	0.5	32,105	1.1	2.7	0.7	0.34	69
S-154 Basin	31,815	0.9	23,087	0.8	12.2	2.9	0.85	428
S-154C Basin	2,134	0.1	2,621	0.1	2.6	0.6	2.66	798
S-191 Basin	120,464	3.5	76,353	2.7	51.3	12.4	0.94	544
South Lake Okeechobee Sub-watershed	**363,141**	**10.5**	**41,278**	**1.4**	**8.7**	**2.1**	**0.05**	**170**
715 Farms (Culvert 12A)	3,353	0.1	0	-	0.0	0.0	0.00	no flow
East Beach Drainage District (Culvert 10)	6,657	0.2	0	-	0.0	0.0	0.00	no flow
East Shore Drainage District (Culvert 12)	8,409	0.2	0	-	0.0	0.0	0.00	no flow
Industrial Canal	13,024	0.4	21,255	0.7	3.0	0.7	0.51	115
S-2 Basin	106,274	3.1	673	0.0	0.2	0.0	0.00	198
S-3 Basin	63,134	1.8	69	0.0	0.0	0.0	0.00	88
S-4 Basin	29,121	0.8	19,281	0.7	5.5	1.3	0.41	230
South Florida Conservancy Drainage District (S-236)	9,931	0.3	0	-	0.0	0.0	0.00	no flow
South Shore/South Bay Drainage District (Culvert 4A)	4,036	0.1	0	-	0.0	0.0	0.00	no flow
S-5A Basin (S-352 West Palm Beach Canal)	119,202	3.5	0	-	0.0	0.0	0.00	no flow
West Lake Okeechobee Sub-watershed (S-77)	**204,094**	**5.9**	**0**	**-**	**0.0**	**0.0**	**0.00**	**no flow**
East Caloosahatchee Basin (S-77)	198,178	5.7	0	-	0.0	0.0	0.00	no flow
Nicodemus Slough South (Culvert 5A)	5,916	0.2	0	-	0.0	0.0	0.00	no flow
Lake Istokpoga Sub-watershed (S-68)	**394,203**	**11.4**	**446,209**	**15.6**	**42.8**	**10.3**	**0.24**	**78**
Lower Kissimmee Sub-watershed [(S-65E) - (S-65)]	**429,188**	**12.4**	**443,778**	**15.5**	**63.4**	**15.3**	**0.33**	**116**
Upper Kissimmee Sub-watershed (S-65)	**1,028,421**	**29.8**	**1,170,539**	**40.9**	**90.9**	**21.9**	**0.19**	**63**
Totals from Lake Okeechobee Watershed	**3,450,475**	**100**	**2,863,497**	**100**	**415**	**100**		
Average Values							**0.27**	**117**
Atmospheric Deposition					35			
Total Loads to Lake Okeechobee					**450**			

a. Values shown in this table only account for contributions from the basins to Lake Okeechobee. It does not capture contributions from these basins to other basins or other surface waters.

Table 8-6. The average surface water inflows, TP loads and concentration, and unit area loads (lb/ac) from subwatersheds to Lake Okeechobee during WY2015.[a]

Source	Area		Discharge		TP Load		Unit Area Load	Average TP Conc.	Runoff
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppb)	(inches)
Fisheating Creek Sub-watershed	318,042	9.2	180,291	6.3	27	6.6	0.19	122	6.8
Indian Prairie Sub-watershed	276,577	8.0	342,374	12.0	90	21.6	0.71	212	14.9
Lake Istokpoga Sub-watershed (S-68)	394,203	11.4	446,209	15.6	43	10.3	0.24	78	13.6
Lower Kissimmee Sub-watershed [(S-65E) - (S-65)]	429,188	12.4	443,778	15.5	63	15.3	0.33	116	12.4
Upper Kissimmee Sub-watershed (S-65)	1,028,421	29.8	1,170,539	40.9	91	21.9	0.19	63	13.7
Taylor Creek/Nubbin Slough Sub-watershed	197,795	5.7	167,617	5.9	77	18.6	0.86	373	10.2
Sub-totals for East, West and South Lake Okeechobee Sub-watersheds	806,248	23.4	112,690	3.9	24	5.8	0.07	173	1.7
Totals from Lake Okeechobee Watershed	3,450,475	100.0	2,863,497	100.0	415	100.0			
Average Values							0.27	117	10.0
Atmospheric Deposition (mt)					35				
Total Loads to Lake Okeechobee (mt)					450				

a. Values shown in this table only account for contributions from the basins to Lake Okeechobee. The East, West, and South Lake Okeechobee subwatersheds drain primarily to the east, west, and south, respectively. This table only represents the portion of runoff from these areas that are discharged to the lake. It does not capture contributions from these basins to other basins or other surface waters.

As shown in **Table 8-7**, during WY2015, TN load to the lake from all drainage basins and atmospheric deposition (estimated as 1,233 mt by James et al. 2005) was 6,191 mt, which is 559 mt less than the last water year. The unit area load of TN averaged 1.40 lbs/ac (1.57 kg/ha) for the Lake Okeechobee Watershed. At the drainage basin level, the highest unit area load of TN was from the L-59W basin (36.17 lbs/ac or 40.51 kg/ha), followed by the C-41A basin (13.02 lbs/ac or 14.58 kg/ha) and the L-61E basin (11.54 lbs/ac or 12.92 kg/ha) during WY2015, and all three drainage basins are located in the Indian Prairie Subwatershed. The FWM TN concentration averaged 1.40 parts per million [ppm or milligrams per liter (mg/L)] for the Lake Okeechobee Watershed. The S-3 basin in the South Lake Okeechobee Subwatershed had the highest FWM TN concentration (3.58 ppm), followed by the S-2 basin (3.18 ppm), in the South Lake Okeechobee Subwatershed and the C-41 basin (2.83 ppm) in the Indian Prairie Subwatershed during WY2015.

At the subwatershed level, the highest TN loads were from the Upper Kissimmee Subwatershed (1,616 mt), followed by the Lake Istokpoga Subwatershed (836 mt) and the Indian Prairie Subwatershed (823 mt) (**Table 8-8)**. The highest unit area load was from the Indian Prairie Subwatershed (6.56 lbs/ac or 7.35 kg/ha), followed by the Lake Istokpoga Subwatershed (4.67 lbs/ac or 5.23 kg/ha) and the Taylor Creek/Nubbin Slough Subwatershed (4.21 lbs/ac or 4.72 kg/ha). In terms of FWM TN concentrations from the subwatersheds, the combined East, West, and South Lake Okeechobee subwatersheds had the highest value (2.30 ppm), followed by the Indian Prairie Subwatershed (1.95 ppm) and the Taylor Creek/Nubbin Slough Subwatershed (1.83 ppm) during WY2015.

Table 8-7. WY2015 surface water inflows, TN loads and concentrations (ppm or mg/L), and unit area loads (lb/ac) from the drainage basins to Lake Okeechobee.[a]

Source	Area		Discharge		TN Load		Unit Area Load	Average TN Conc.
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppm)
East Lake Okeechobee Sub-watershed	**239,013**	6.9	**71,412**	**2.5**	**196.8**	**4.0**	**1.82**	**2.23**
C-44/S-153/Basin 8 (S-308 at St. Lucie Canal)	132,572	3.8	16,876	0.6	29.5	0.6	0.49	1.42
L-8 Basin (Culvert 10A)	106,440	3.1	54,536	1.9	167.3	3.4	3.47	2.49
Fisheating Creek Sub-watershed	**318,042**	9.2	**180,291**	**6.3**	**356.5**	**7.2**	**2.47**	**1.60**
Fisheating Creek at Lakeport/L-61W Basin	298,713	8.7	170,574	6.0	335.4	6.8	2.48	1.59
Nicodemus Slough North (Culvert 5)	19,329	0.6	9,717	0.3	21.2	0.4	2.42	1.77
Indian Prairie Sub-watershed	**276,577**	**8.0**	**342,374**	**12.0**	**823.3**	**16.6**	**6.56**	**1.95**
C-40 Basin [(S-72) – (S-68)]	24,076	0.7	10,407	0.4	32.3	0.7	2.96	2.52
C-41 Basin [(S-71) – (S-68)]	112,880	3.3	45,409	1.6	158.3	3.2	3.09	2.83
C-41A Basin [(S-84) – (S-68)]	57,748	1.7	151,475	5.3	341.1	6.9	13.02	1.83
L-48 Basin (S-127 total)	20,798	0.6	19,261	0.7	49.7	1.0	5.27	2.09
L-49 Basin (S-129 total)	11,966	0.3	8,595	0.3	14.4	0.3	2.65	1.36
L-59E Basin [(G-33)+(G-34)]	12,589	0.4	5,491	0.2	14.5	0.3	2.55	2.15
L-59W Basin (G-74)	6,596	0.2	46,357	1.6	108.2	2.2	36.17	1.89
L-60E Basin (G-75)	4,944	0.1	12,042	0.4	25.9	0.5	11.54	1.74
L-60W Basin (G-76)	3,453	0.1	2,531	0.1	5.6	0.1	3.57	1.79
L-61E Basin	14,407	0.4	31,709	1.1	57.4	1.2	8.78	1.47
S-131 Basin	7,122	0.2	9,096	0.3	15.9	0.3	4.92	1.42
Taylor Creek/Nubbin Slough Sub-watershed	**197,795**	**5.7**	**167,617**	**5.9**	**378.1**	**7.6**	**4.21**	**1.83**
S-133 Basin	25,626	0.7	33,451	1.2	68.1	1.4	5.86	1.65
S-135 Basin	17,756	0.5	32,105	1.1	56.5	1.1	7.01	1.43
S-154 Basin	31,815	0.9	23,087	0.8	62.5	1.3	4.33	2.20
S-154C Basin	2,134	0.1	2,621	0.1	9.0	0.2	9.34	2.80
S-191 Basin	120,464	3.5	76,353	2.7	182.0	3.7	3.33	1.93
South Lake Okeechobee Sub-watershed	**363,141**	**10.5**	**41,278**	**1.4**	**123.4**	**2.5**	**0.75**	**2.42**
715 Farms (Culvert 12A)	3,353	0.1	0	-	0.0	0.0	0.00	no flow
East Beach Drainage District (Culvert 10)	6,657	0.2	0	-	0.0	0.0	0.00	no flow
East Shore Drainage District (Culvert 12)	8,409	0.2	0	-	0.0	0.0	0.00	no flow
Industrial Canal	13,024	0.4	21,255	0.7	54.1	1.1	9.16	2.06
S-2 Basin	106,274	3.1	673	0.0	2.6	0.1	0.05	3.18
S-3 Basin	63,134	1.8	69	0.0	0.3	0.0	0.01	3.58
S-4 Basin	29,121	0.8	19,281	0.7	66.3	1.3	5.02	2.79
South Florida Conservancy Drainage District (S-236)	9,931	0.3	0	-	0.0	0.0	0.00	no flow
South Shore/South Bay Drainage District (Culvert 4A)	4,036	0.1	0	-	0.0	0.0	0.00	no flow
S-5A Basin (S-352 West Palm Beach Canal)	119,202	3.5	0	-	0.0	0.0	0.00	no flow
West Lake Okeechobee Sub-watershed	**204,094**	**5.9**	**0**	**-**	**0.0**	**0.0**	**0.00**	no flow
East Caloosahatchee Basin (S-77)	198,178	5.7	0	-	0.0	0.0	0.00	no flow
Nicodemus Slough South (Culvert 5A)	5,916	0.2	0	-	0.0	0.0	0.00	no flow
Lake Istokpoga Sub-watershed (S-68)	**394,203**	**11.4**	**446,209**	**15.6**	**835.8**	**16.9**	**4.67**	**1.52**
Lower Kissimmee Sub-watershed [(S-65E) - (S-65)]	**429,188**	**12.4**	**443,778**	**15.5**	**627.7**	**12.7**	**3.22**	**1.15**
Upper Kissimmee Sub-watershed (S-65)	**1,028,421**	**29.8**	**1,170,539**	**40.9**	**1616.2**	**32.6**	**3.46**	**1.12**
Totals from Lake Okeechobee Watershed	**3,450,475**	**100**	**2,863,497**	**100**	**4,958**	**100**		
Average Values							**3.17**	**1.40**
Atmospheric Deposition					1,233			
Total Loads to Lake Okeechobee					**6,191**			

a. Values shown in this table only account for contributions from the basins to Lake Okeechobee. It does not capture contributions from these basins to other basins or other surface waters.

Table 8-8. The average surface water inflows, TN loads and concentrations (ppm or mg/L), and unit area loads (lb/ac) from subwatersheds to Lake Okeechobee during WY2015.[a]

Source	Area		Discharge		TN Load		Unit Area Load	Average TN Conc.	Runoff
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppm)	(inches)
Fisheating Creek Sub-watershed	318,042	9.2	180,291	6.3	357	7.2	2.47	1.60	6.8
Indian Prairie Sub-watershed	276,577	8.0	342,374	12.0	823	16.6	6.56	1.95	14.9
Lake Istokpoga Sub-watershed (S-68)	394,203	11.4	446,209	15.6	836	16.9	4.67	1.52	13.6
Lower Kissimmee Sub-watershed [(S-65E) - (S-65)]	429,188	12.4	443,778	15.5	628	12.7	3.22	1.15	12.4
Upper Kissimmee Sub-watershed (S-65)	1,028,421	29.8	1,170,539	40.9	1,616	32.6	3.46	1.12	13.7
Taylor Creek/Nubbin Slough Sub-watershed	197,795	5.7	167,617	5.9	378	7.6	4.21	1.83	10.2
Sub-totals for East, West and South Lake Okeechobee Sub-watersheds	806,248	23.4	112,690	3.9	320	6.5	0.88	2.30	1.7
Totals from Lake Okeechobee Watershed	3,450,475	100.0	2,863,497	100.0	4,958	100.0			
Average Values							3.17	1.40	10.0
Atmospheric Deposition (mt)					1,233				
Total Loads to Lake Okeechobee (mt)					6,191				

a. Values shown in this table only account for contributions from the basins to Lake Okeechobee. The East, West, and South Lake Okeechobee subwatersheds drain primarily to the east, west and south, respectively. This table only represents the portion of runoff from these areas that are discharged to the lake. It does not capture contributions from these basins to other basins or other surface waters.

Ambient Water Quality Data Analysis

The long-term tributary or ambient water quality stations under projects KREA and TCNS consist of river and basin-level monitoring locations that are sampled on a biweekly basis when flow is present. This analysis also considers concentration data from tributary-level monitoring sites collected under project the Lake Okeechobee Tributary Loadings Project (OKUSGS), which was initiated in 2003 (**Figure 8-5**). It is also important to note that the tributary concentration stations for C-41 and C-41A are located well upstream compared to the basin loading stations discussed earlier. TP and TN concentrations were collected at these 37 monitoring stations (7 OKUSGS sites and 31 ambient SFWMD sites) during WY2015. A site usually used for assessment of water quality entering the Taylor Creek STA was added to this analysis because it represents the water in Taylor Creek directly downstream of an OKUSGS site discontinued in 2009. This site now has five years of data that can be added to the long-term data set for the Taylor Creek drainage basin. Any additional long term-data within the Taylor Creek basin will be useful in the assessment of this priority basin. The ambient water quality network has primarily focused on the assessment of those basins considered critical to the nutrient concentration issues in the Lake Okeechobee Watershed (**Figure 8-5**). Additional water quality assessment in the watershed is done under the LOWA monitoring network, which supports the WOD BMP Program, Chapter 40E-61, F.A.C., and the results of these efforts are discussed in Chapter 4 and Appendix 4-3 of this volume.

Concentration data from sites established for the OKUSGS Project are included in statistical summaries (**Tables 8-9** and **8-10**). This project was formally run by USGS under contract from the District, FDACS, and USACE and consisted of 16 locations equipped with auto-samplers programmed to collect flow-proportional samples. This project was reduced and now includes two sites with auto-samplers collecting on a timed program, and five of the original stations are sampled via grab collections. All the seven water quality stations and five of the historical USGS program sites are still collecting flow data via a contract from FDACS. Several of the OKUSGS water quality sampling sites were leveraged against existing nearby KREA or TCNS sites. Redundancy between the two programs was eliminated once the District brought the water quality sampling in-house in 2011. Future reporting will summarize loadings from these 12 tributary sites once there is enough long-term data to establish statistical significance and the historical data are verified by the District. The TN samples from unrefrigerated auto-samplers presented in this assessment should be viewed as experimental. Until recently, there was no FDEP approved method to maintain TN samples in an unrefrigerated environment over a seven-day period if the TN was calculated by adding total Kjeldahl nitrogen (TKN) and nitrate + nitrite (NO_x) analyses. The District laboratory is now certified to analyze samples for TN directly. TN data collected via auto-sampler in the future will have much more validity. The period of record for TN is lacking from several of the basins and this data may help to provide preliminary insight into additional sources of nitrogen in the watershed.

Table 8-9. Statistics of TP data collected from the ambient network in the Lake Okeechobee Watershed. WY2015 values are included to show annual changes. [Note: Std Dev – Standard Deviation.]

BASIN	WY2006-2014 (TP)						WY2015 (TP)					
	Mean (ppb)	Median (ppb)	Std Dev	Number of Samples	Max (ppb)	Min (ppb)	Mean (ppb)	Median (ppb)	Std Dev	Number of Samples	Max (ppb)	Min (ppb)
C-41	280	186	263	206	1921	27	243	229	151	15	651	99
C-41A	75	73	28	417	170	6	87	84	25	22	144	30
Fisheating Creek	236	193	179	429	1283	17	199	177	81	20	417	114
Lake Istokpoga	110	86	70	477	474	26	123	111	58	105	414	43
S-65A	74	66	40	413	271	23	63	58	29	36	168	29
S-65BC	81	68	42	410	273	22	65	63	25	36	120	33
S-65D	248	160	224	929	1494	11	197	100	211	89	1009	27
S-65E	439	239.5	531	290	3330	23	446	157	763	56	4855	30
S-154	604	520	434	300	2330	14	479	413	342	22	1514	101
S-191TC (Taylor Creek)	395	329	290	2240	2909	14	360	277	254	191	1756	53
S-191NS (Nubbin Slough)	427	391	256	853	2390	10	413	343	325	93	2270	57

Table 8-10. Statistics of TN data collected from the ambient network in the Lake Okeechobee Watershed. WY2015 values are included to show annual changes. [Note: Std Dev – Standard Deviation.]

BASIN	WY2006-2014 (TN)						WY2015 (TN)					
	Mean (ppm)	Median (ppm)	Std Dev	Number of Samples	Max (ppm)	Min (ppm)	Mean (ppm)	Median (ppm)	Std Dev	Number of Samples	Max (ppm)	Min (ppm)
C-41	2.32	1.99	1.11	210	5.90	0.15	2.13	2.12	0.75	15	4.24	1.34
C-41A	1.52	1.59	0.64	294	5.80	0.00	1.54	1.44	0.30	10	2.15	1.26
Fisheating Creek	2.37	2.05	1.12	397	7.90	0.29	1.94	1.83	0.54	19	2.87	1.25
Lake Istokpoga	1.39	1.37	0.30	314	2.43	0.46	1.16	1.13	0.13	49	1.46	0.92
S-65A	1.35	1.26	0.41	411	3.69	0.77	1.23	1.14	0.28	33	2.35	0.88
S-65BC	1.28	1.19	0.30	410	2.38	0.58	1.13	1.11	0.17	33	1.52	0.87
S-65D	1.63	1.56	0.53	898	6.47	0.49	1.38	1.36	0.27	89	2.19	0.82
S-65E	2.21	1.92	1.22	291	12.65	0.45	1.89	1.46	1.27	54	6.70	0.28
S-154	2.29	2.29	0.74	295	4.75	0.06	2.46	2.41	0.54	22	3.84	1.71
S-191TC (Taylor Creek)	1.98	1.80	1.15	1907	13.37	0.14	2.06	1.88	1.45	115	14.70	0.63
S-191NS (Nubbin Slough)	2.16	2.04	0.91	835	10.83	0.57	1.90	1.85	1.28	87	11.80	0.59

For WY2015, the mean TP concentrations of the 11 basins—developed from the 37 sites—ranged from 63 ppb at the S-65A basin to 479 at the S-154 basin (**Table 8-9**). For comparison purpose, data from nine-year averages for WY2006–WY2014 are also included. Due to its size and the numbers of monitoring stations, the S-191 basin (Taylor Creek/Nubbin Slough) is further divided into two subbasins: Taylor Creek (S-191TC) and Nubbin Slough (S-191NS). During WY2015, eight of the basins displayed lower TP concentrations than during the WY2006–WY2014 period of record, while three displayed higher TP concentrations. The highest mean TP concentration at the S-154 basin (479 ppb) was followed by S-65E (446 ppb) and S-191NS basins (413 ppb). Among the four original priority basins (S-154, S-191, S-65D, and S-65E), S-65D continued to have a relatively lower TP concentration (197 ppb) and both S-191 and S-154 basins have concentrations that are lower than the long-term averages. The WY2015 mean TP concentrations from the C-41A basin displayed the highest percent increase (17 percent) when compared with data collected in WY2006–WY2014. The basins with the highest percent decrease in TP concentrations were the S-65D and S-154 basins (both with a 21 percent decrease), followed by the S-65BC basin (20 percent decrease).

TN values are calculated by adding NO_x and TKN concentrations for the S-65E structure location due to a permit mandate. TN values were obtained directly for all other sites. The S-154 basin had the highest mean TN value (2.46 ppm) in WY2015, followed by the C-41 (2.13 ppm) and S-191TC (2.06 ppm) basins (**Table 8-10**). The mean TN values were lower in eight of the basins and higher in three of the 11 basins in WY2015 as compared to the WY2006–WY2014 values. Two of the basins with the greatest decrease in TN concentrations in WY2015 compared to the WY2006–WY2014 values were Fisheating Creek (18 percent decrease) and Lake Istokpoga (17 percent decrease).

MODELING, RESEARCH, DEMONSTRATION AND ASSESSMENT PROJECTS

The District, in cooperation with the FDACS, FDEP, University of Florida Institute of Food and Agricultural Sciences, and other agencies and interested parties, has implemented a comprehensive research and assessment program for the lake and its watershed. Ten research, demonstration, and assessment projects were under way or completed in WY2015 (**Table 8-11**). More information on some of the projects can be found on the District's website at www.sfwmd.gov/okeechobee.

Table 8-11. Status of Lake Okeechobee Watershed and lake modeling, demonstration projects, research, and assessment projects during WY2015.

Project Name (Investigator)	Description, Major Objectives and Results	Status
PN-Budget Tool Applications to Tributaries in the Lake Kissimmee Drainage Area (SFWMD)	The overall goal of this project is to apply the PN-Budget tool to Lake Cypress, Lake Hatchineha, and Lake Kissimmee drainage basins to identify the hydrologic and loading data needed to develop a nutrient budget for these lakes. The PN-Budget tool can be used to evaluate various phosphorus control programs to maximize water quality improvements from a drainage area. Specific objectives are to (1) select the area of interest based on the reaches and monitoring locations that need to be studied, (2) compare the area of interest results with the available monitoring data and adjust the model inputs if needed; and (3) obtain nutrient loading data needed for the lake nutrient budget analysis. The project was completed in May 2015 and results are included in Chapter 9 of this volume.	Completed
Lake Okeechobee Pre-drainage Characterization (To be determined)	The Lake Okeechobee Pre-drainage Characterization Project uses the Watershed Assessment Model (WAM) (SWET 2011a, 2011b) to compare existing hydrologic conditions with historical conditions that existed before significant human influences took place (i.e., pre-drainage 1850s). In 2013, the coordinating agencies decided to perform the sensitivity analysis and uncertainty analysis of WAM prior to completion of the pre-drainage characterization analysis as a means to improve the model's performance. Therefore, the Lake Okeechobee Pre-drainage Characterization Study was placed on hold pending the completion of the sensitivity analysis and uncertainty analysis that is currently under way.	On-hold
WAM Sensitivity and Uncertainty Analysis (FDACS/ SFWMD)	This project involves implementing the two remaining recommendations for enhancing WAM that are included in the Peer Review of the Watershed Assessment Model (WAM) (Graham et al. 2009). The two recommendations for enhancing WAM are the performance of a sensitivity analysis and an uncertainty analysis. All the other five recommendations by the peer review panel have been completed. As part of implementing the sensitivity and uncertainty analyses, WAM will be recalibrated resulting in increased confidence of the model's results, it will add a margin-of-safety value derived through a formal uncertainty analysis and the sensitivity analysis will allow us to identify the model's most sensitive parameters, which can then be refined as appropriate. The project was started in February 2015 and is expected to be completed in 2016.	Ongoing
Northern Everglades Water Storage (SFWMD)	It is anticipated that this project will help inform the reformulation of the Comprehensive Everglades Restoration Plan (CERP) LOW Project which USACE prioritized in the November 2015 CERP Integrated Delivery Schedule. The current focus of this project is a subwatershed suitability analysis for various types of water storage features. Storage features being considered are deep and shallow storage, aquifer storage and recovery and water storage on ranchlands and fallow citrus (dispersed water management). Future tasks will be dependent on the CERP LOW scope and schedule, but they may include a subwatershed storage analysis and a cost effectiveness analysis.	Ongoing
Evaluation of Storage and Water Quality Alternatives at the Grassy Island and Brady Ranch Properties (SFWMD)	The objective of this study is to evaluate water quality and storage options for the District's Taylor Creek/Grassy Island and Brady Ranch properties located in the Taylor Creek/Nubbin Slough Subwatershed. The modeling assumptions and constraints, boundary conditions and baseline conditions tasks are complete. Additionally, screening criteria and preliminary alternatives have been drafted. The next step includes simulating alternative model runs and screening the preliminary alternatives by applying the screening criteria. The completion of the project is anticipated in 2016.	Ongoing
Development of new or revised in-lake ecological performance measures (SFWMD)	New and/or revised performance measures relating SAV, periphyton, fisheries, and cyanobacterial blooms to Lake Okeechobee water levels were developed based on long-term monitoring data sets. These performance measures are being used to evaluate potential ecological benefits that may accrue over different stage durations. Current efforts are directed at analyzing and interpreting the information generated by this effort.	Ongoing

Table 8-11. Continued.

Project Name (Investigator)	Description, Major Objectives and Results	Status
Wading Bird Foraging Prediction Model (SFWMD)	This project involves developing an ecological model to better understand and predict how wading birds respond to environmental and climatological changes in Lake Okeechobee. Ecological models that predict outcomes of such changes can be useful tools in understanding the effects of management decisions and in evaluating restoration strategies. There may be limitations to fully understanding cause-and-effect relationships since local and regional conditions outside of the lake can influence responses on the lake. However, completing a Lake Okeechobee model will bring us one step closer to better understanding wading bird population ecology in the Greater Everglades watershed.	Ongoing
Evaluation and Development of Alternative Monitoring Techniques[a] (SFWMD)	Satellite imagery is now being used routinely to inform management. The District is evaluating or helping to develop new methods for monitoring ecological parameters in Lake Okeechobee. These include refining a satellite imagery tool for use of algal bloom monitoring on Lake Okeechobee, merging and interpolating existing bathymetric data sets to create a 5-foot digital elevation model of Lake Okeechobee using Lowrance sonar technology to improve SAV monitoring. The 5-foot digital elevation model of Lake Okeechobee was complete in WY2015. The use of Lowrance sonar technology is still in the development phase.	Ongoing
Lake Okeechobee Littoral Marsh Aquatic Plant Communities Food Web Characteristics[a] (SFWMD)	The establishment of marsh EAV habitat in formerly SAV nearshore areas may have resulted in a significantly modified nearshore food web. However, relatively little data have been collected to document changes among the littoral food web trophic levels. To facilitate habitat utilization comparisons among three of the dominant littoral marsh aquatic plant habitats, throw-trap sampling is being conducted to collect data on water quality and on ecological attributes including fish, macroinvertebrates, periphyton, phytoplankton, and zooplankton (plankton).	Ongoing
Emergent Vegetation Decomposition and Nutrient Cycling Rates[a] (SFWMD)	Major differences in nutrient cycling occur in Lake Okeechobee at low versus high water levels (James and Havens 2005). Periodically, rapid increases in lake levels occur as a result of extreme weather events such as hurricanes and tropical storms. Increased waves and turbulence associated with these events uproot and tear emergent vegetation leading to significant amounts of fresh litter. As this fresh litter decomposes, the nutrients they contain are likely introduced to the water column contributing to the increased nutrient concentrations observed at higher water levels. To understand how plant decomposition is affected by such rapid water increases, and how this decomposition contributes to nutrient dynamics under high water conditions, this study tests a standard method to measure fresh plant decomposition under both wet and dry conditions. This information will increase the reliability of predictions from the Lake Okeechobee Water Quality Model (James et al. 2005, James 2013) and give a better understanding of the effects of rapid increases in lake level on the water quality of Lake Okeechobee. Field work and analysis of the year one pilot study was completed during WY2015 and a year two study is under way.	Ongoing

a. Additional information on this project is available in the *Lake Okeechobee Monitoring Results* section of this chapter.

LAKE STATUS

PERFORMANCE MEASURES

Measurements of TP, Chla, phytoplankton, SAV, and water levels are used as quantitative in-lake performance measures. These measures describe the status of the ecosystem and its responses to implemented restoration programs. Measures are five-year averages to ensure consistency with TMDL reporting, reduce year-to-year variation due to climate and hydrology, and improve understanding of underlying trends. These values are compared to quantitative restoration goals (**Table 8-12**). The Lake Okeechobee Protection Program Report provides a technical foundation for these restoration goals (SFWMD et al. 2004). The WY2015 averaged observations document this year's water quality and lake level conditions.

Despite a 26 percent reduction in TP loads and 8 percent reduction of TN loads in WY2015 compared to WY2014, there were some nutrient and biological performance measures that declined. These included pelagic and nearshore TP which increased by 14 and 26 percent, respectively. Total and inorganic nitrogen to phosphorus ratios were also lower (**Table 8-12**).

The diatom to cyanobacterial ratio failed to meet the biological performance measure goal of > 1.5, although the five-year average remained above the goal threshold. Diatom to cyanobacteria ratios declined, the frequency of algal bloom was higher, and SAV coverage in August 2014 was slightly lower than in the previous year; and the SAV coverage goal was not reached in the WY2015 survey although the five-year average was just 8 percent short of the annual goal of 40,000 acres. The five-year average indicated that 65 percent of the SAV was comprised of vascular plants, which met the annual performance criterion. (August 2010–August 2014; **Table 8-12**). A further evaluation of the last survey is provided in the *Submerged Aquatic Vegetation* section of this chapter. The single improvement in WY2015 was water clarity (see below) (**Table 8-12**).

Calculation of Secchi to total water depth ratio indicates the depth of light penetration in the water column. Generally, a Secchi depth to total depth ratio of 0.5 indicates that sufficient light is reaching the bottom to allow for the growth of SAV. However, a more stringent criterion of the Secchi depth being visible on the bottom (a Secchi to total depth ratio of 1) is used for this performance measure. This water year, an updated assessment was undertaken to more accurately evaluate the nearshore water clarity performance measure since the elimination of sampling at a number of nearshore water quality sites resulted in an insufficient number of data collection sites. Data were obtained for 30 SAV grid locations from May to September of each year. This included measurements taken in the quarterly SAV monitoring project and a subset of measurements using the same grid locations extracted from the annual August SAV mapping study. The percent of samples where the Secchi disk reached the bottom of the water column was determined for WY2011–WY2015. These percentages were averaged for the five-year period. For WY2015, 53 percent of the samples met the criteria, an increase from 23 percent for the previous year. For the five-year period, the average percent of samples meeting the criteria was 54 percent.

Overall, lake stage declined gradually from 15.25 ft (4.65 m) NGVD29 in January to 12.24 ft (3.73 m) NGVD29 in June during the annual winter/spring recession. However, because of higher than normal flow into the lake from January to April, two reversals greater than 0.2 ft (0.061 m) (occurred, one in February and the other in April; see **Figure 8-7** below). Thus, the stage recession goal was partially met (**Table 8-12**). Lake stage remained above the 10 ft (3.05 m) goal and below the 17 ft (5.18 m) goal throughout the year, meeting the low and high lake stage criteria, respectively.

Table 8-12. Summary of Lake Okeechobee rehabilitation performance measures, rehabilitation program goals, and lake conditions for the five-year average (WY2011–WY2015), WY2015, and WY2014.

Performance Measure	Goal	Five-Year Average (WY2011–WY2015)	WY2015	WY2014
Nutrients				
TP Load	140 metric tons per year (mt/yr)	436 mt/yr	450 mt/yr	609 mt/yr
Nitrogen Load	N/A[a]	5,374 mt/yr	6,191 mt/yr	6,750 mt/yr
Pelagic TP	40 ppb	117 ppb	134 ppb	118 ppb
Pelagic TN	N/A	1.39 ppm	1.36 ppm	1.28 ppm
Pelagic soluble reactive phosphorus (SRP)	N/A	38 ppb	43 ppb	30 ppb
Pelagic dissolved inorganic nitrogen (DIN)	N/A	168 ppb	155 ppb	139 ppb
Pelagic TN:TP[b]	> 22:1	11.8:1	10.2:1	10.8:1
Pelagic DIN:SRP	> 10:1	4.5:1	3.6:1	4.6:1
Nearshore TP	Below 40 ppb	71 ppb	97 ppb	76 ppb
Biota				
Plankton nutrient limitation	Phosphorus > Nitrogen	Nitrogen >>> Phosphorus	Nitrogen >>> Phosphorus	Nitrogen >>> Phosphorus
Diatom:cyanobacteria ratio[c]	> 1.5	1.6	1.2	1.3
Algal bloom frequency	< 5% of pelagic Chla exceeding 40 μg/L	11.50%	16%	14%
SAV[d]	Total SAV > 40,000 acres	37,043 acres	31,877 acres	33,854 acres
	Vascular SAV > 50% of total acres	65%	67%	83%
Physical Parameters				
Water clarity[e]	Secchi disk visible on lake bottom at all nearshore SAV sampling locations from May through September	54%	53%	23%
Hydrology				
Extremes in low lake stage (current water year)	Maintain stages above 10 ft	N/A	Goal attained	Goal attained
Extremes in high lake stage (current water year)	Maintain stages below 17 ft; stage not exceeding 15 ft for more than 4 months	N/A	Goal attained	Goal attained
Spring recession (January to June 2015)	Stage recession from near 15.5 ft in January to near 12.5 ft in June	N/A	Goal partially attained (January stage declined from 15.23 to 12.24 ft in June with two reversals of more than 0.2 ft)	Goal partially attained (January stage just over 14 ft to 12.98 in June. A reversal occurred in June)

a. N/A – Not applicable

b. Calculated by weight.

c. Mean values from May 2009 to February 2013

d. Mean yearly acreages (from August 2010–2014 maps)

e. SAV transparency readings taken from May to September 2014

HYDROLOGY

Lake Okeechobee was at an elevation of 13.05 ft (3.98 m) NGVD29 on May 1, 2014, which placed water levels in the Base Flow Subband (**Figure 8-7**). Over 1.9 million ac-ft of water was released in WY2015. Regulatory releases from the lake to the estuaries comprised a third (0.7 million ac-ft) of this discharge and were made throughout the water year based on SFWMD adaptive protocols (SFWMD 2010). Pulse releases to the east and west coast estuaries occurred from mid-July to mid-September 2014 and from mid-October 2014 through the end of April 2015. These discharges were primarily to the Caloosahatchee River through S-77 (704,000 ac-ft), with smaller, less frequent releases being made to the St. Lucie Estuary through S-308 (129,000 ac-ft; see Table 7 in the 2015 SFER – Volume III, Appendix 4-1; Hansing et al. 2015). Releases of 1.2 million ac-ft were made south through the S-351, S-352, and S-354 structures and Culvert 10A, constituting approximately half of all the water discharged from the lake during WY2015, with 585,000 ac-ft of that water being directed to the Everglades STAs. Lake stage reached a minimum level of 12.38 ft (3.77 m) NGVD29 on June 12, 2014, and its maximum level for the water year of 16.01 ft (4.88 m) NGVD29 on October 23, 2014.

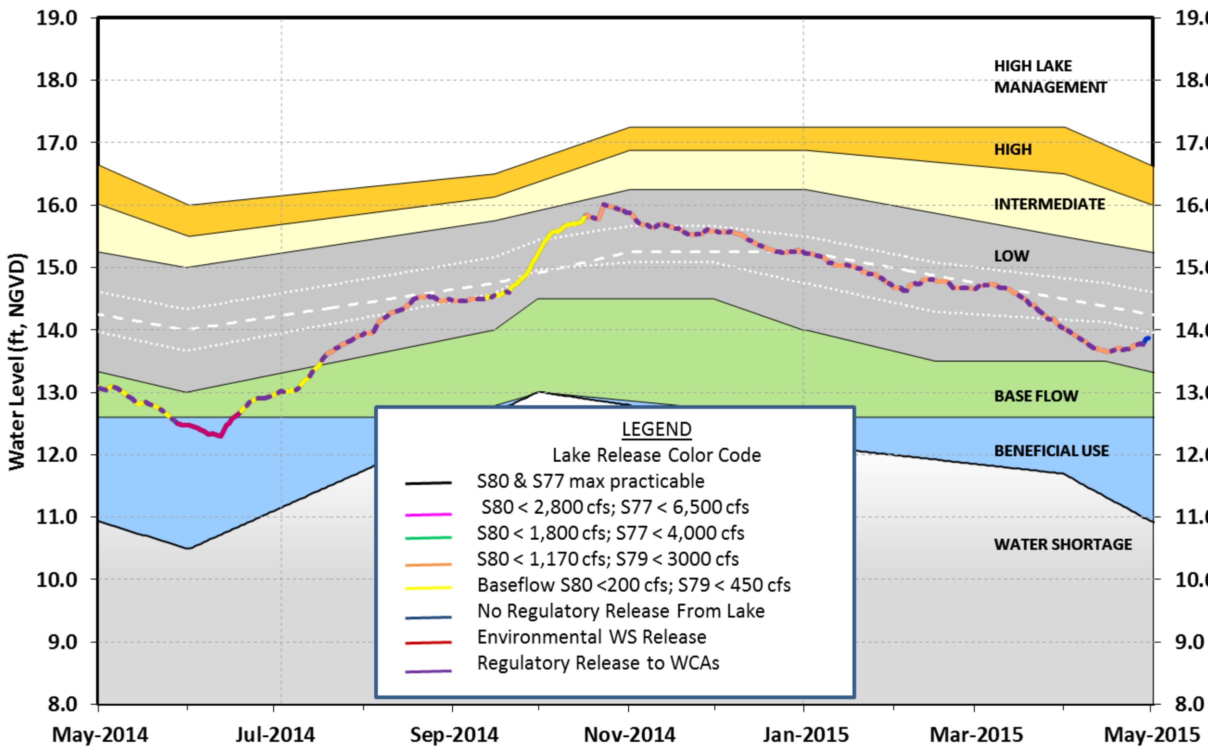


Figure 8-7. Annotated Lake Okeechobee stage hydrograph.

NUTRIENT BUDGETS

TP loads to the lake from tributaries and atmospheric deposition [estimated as 35 metric tons per year (mt/yr), FDEP 2001) totaled 450 mt in WY2015 (**Table 8-12** and **Figure 8-8**). This is a 26 percent reduction from the previous year despite total discharge flows to the lake being nearly the same as WY2014 (within 2 percent) (see Tables 6 and 14 from the 2015 SFER – Volume III, Appendix 4-1; Hansing et al. 2015). The load reduction is attributed to cleaner water discharging to the lake with a FWM TP concentration of 117 ppb. This is less than the in-lake TP concentration estimate of 134 ppb (**Figure 8-9**). As previously noted, the source of a majority of this cleaner water was the Upper Chain of Lakes (S-65), which discharged over 1.171 million ac-ft of water in WY2015 (an increase of 53 percent from WY2014). The average FWM TP concentration at S-65 was 63 ppb, which was an 18 percent reduction from the previous year.

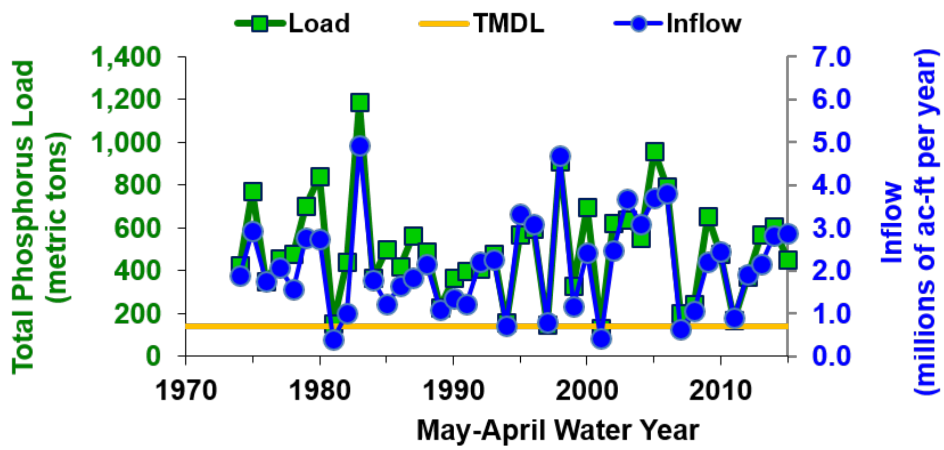


Figure 8-8. Timelines of water year TP load and inflow entering Lake Okeechobee from its tributaries calculated from the lake phosphorus budget.

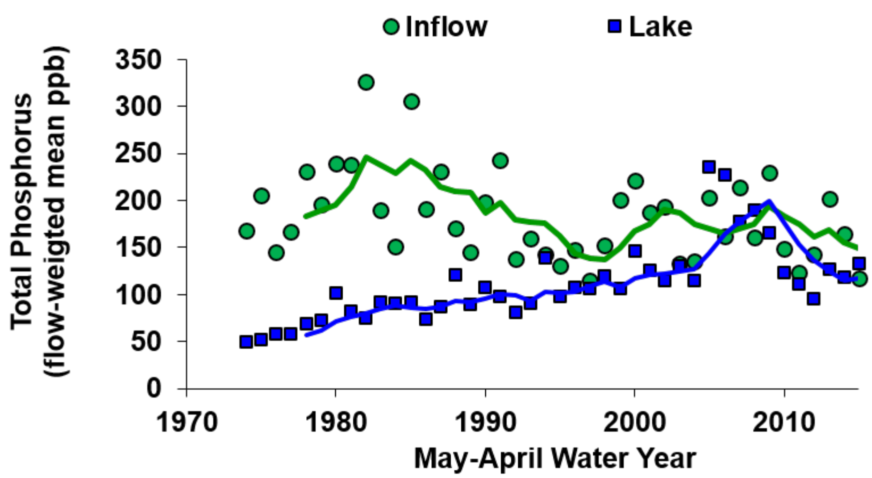


Figure 8-9. Timelines of inflow and lake average TP concentrations (five-year moving average trend lines calculated from the lake phosphorus budget).

Mean lake TP mass in WY2015 was higher than the previous water year due to increased overall TP concentrations (**Table 8-13** and **Figure 8-8**). Loads out of the lake in WY2015 were lower than in WY2014 as discharge was lower by 24 percent. As with the load into the lake, the net load (inputs minus outputs) in WY2015 was 152 mt, or a 45 percent reduction from WY2014. Sediment accumulation was also lower than the previous year, resulting in a net sedimentation coefficient of 0.35 (**Table 8-13** and **Figure 8-10**). A low sedimentation coefficient indicates that the lake absorbed less excess TP load from the watershed. The sedimentation coefficient is based on the estimated removal of TP from the water column to the sediments divided by the average water column mass in the year. Lower coefficients indicate smaller portions of the mass are removed. The TP budget for Lake Okeechobee estimates the removal of phosphorus from the water column by subtracting the net change in lake mass (estimated from the beginning of the water year to the beginning of the next water year) from net loads (atmospheric deposition + external loads – discharge from the lake). Note that TP analyses includes phosphorus in phytoplankton, bacteria, and organic and inorganic particles and does not differentiate among them. Thus, the net sedimentation is an estimate of the sum of settling, resuspension, diffusion, and adsorption to the sediments and the uptake by phytoplankton, and settling out cannot be distinguished based on this analysis.

TP concentrations in the water column declined from a high of 227 ppb in WY2006 to 96 ppb in WY2013. The current WY2015 value is 134 ppb (**Figure 8-9**). The higher concentration in WY2015 compared to WY2014 (118 ppb) can be attributed to higher water levels in the dry winter season than in WY2014. This season period is windier than the summer wet season, resulting in greater sediment resuspension and internal nutrient loading to the water column.

For WY2015, the sediment coefficient value was 0.36 per year (**Table 8-13**), which was lower than the 10-year average value of 0.50 per year. The value for WY2015 was also lower than the previous year's value primarily because of the small change of storage in the lake and the lower net loads. Over the past four decades, the sediment coefficient declined from around 2.5 in the 1970s to below 1 in the 1990s (**Figure 8-10)** (Janus et al. 1990, James et al. 1995, Havens and James 2005), but it appears that the values are again increasing**.**

Table 8-13. Phosphorus budget for Lake Okeechobee (WY2006–WY2015).

May 1–April 30 Water Year	Mean Lake TP Mass (mt)	Net Change in Lake Content[a]	Load In[b] (mt)	Load Out (mt)	Net Load[c] (mt)	Sediment Accumulation[d]	Net Sedimentation Coefficient
2006	1,175	-186	795	798	-3	183	0.16
2007	599	-288	203	184	19	307	0.51
2008	459	113	246	27	219	106	0.23
2009	608	-257	656	243	413	670	1.10
2010	500	283	481	79	402	119	0.24
2011	439	-320	170	210	-40	280	0.64
2012	318	11	373	88	285	274	0.86
2013	545	280	569	126	443	163	0.30
2014	542	-34	609	332	277	311	0.57
2015	604	-63	450	298	152	215	0.36
Average	**579**	**-46**	**455**	**238**	**217**	**263**	**0.50**

a. Net change from the start (May 1) through the end (April 30) of each water year

b. Includes 35 mt/yr to account for atmospheric deposition

c. Difference between load in and load out

d. Difference between net change in lake content and net load (positive value is accumulation in sediments)

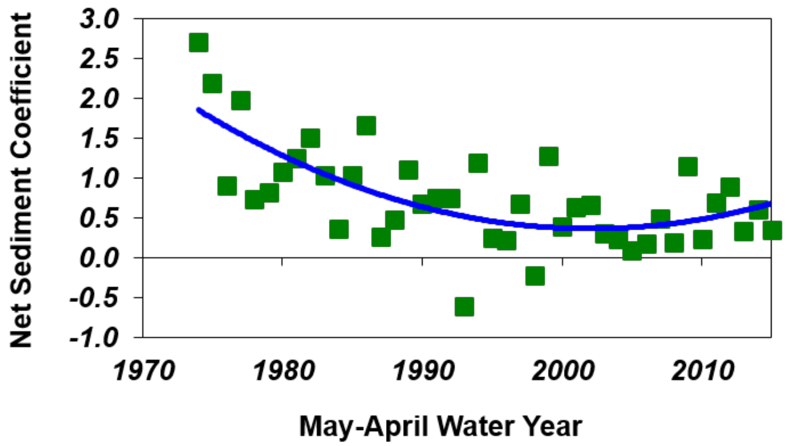


Figure 8-10. Timeline of the net sedimentation coefficient calculated from the lake phosphorus budget. Trend line is a second-order polynomial.

TN loads to the lake were slightly lower than the previous water year, showing an 8 percent reduction (**Table 8-14** and **Figure 8-11**). This is reflected in the smaller difference of TN inflow weighted concentration as compared to TP (**Figure 8-12**). Discharge TN loads also were lower than the previous year (**Table 8-14**) as reflected by the lower water discharge from the lake. Unlike the phosphorus budget, the net TN load in WY2015 was higher than WY2014. The lake also removed a larger amount of nitrogen as compared to the previous water year. This removal resulted in an adsorption coefficient that is higher than both the previous year and the 10-year average. These contrasting results to phosphorus suggest the significant role that biological processes (nitrogen uptake and denitrification) have on the lake (James et al. 2011).

Table 8-14. Nitrogen budget for Lake Okeechobee (WY2006–WY2015).

May 1–April 30 Water Year	Mean Lake TN Mass	Net Change in Lake Content[a]	Load In[b] (mt)	Load Out (mt)	Net Load[c] (mt)	Lake Adsorption[d]	Net Adsorption Coefficient
2006	9,389	-2,692	7,992	8,048	-56	2,636	0.28
2007	4,873	-3,460	2,965	2,023	942	4,402	0.90
2008	3,772	2,128	3,393	392	3,001	873	0.23
2009	6,566	-1,075	6,689	2,841	3,848	4,923	0.75
2010	6,659	2,735	6,325	1,106	5,219	2,484	0.37
2011	5,762	-3,402	2,913	3,018	-105	3,297	0.57
2012	4,427	487	4,620	1,460	3,160	2,673	0.60
2013	6,178	1,705	6,397	1,879	4,518	2,813	0.46
2014	5,900	-81	6,750	4,258	2,492	2,573	0.44
2015	6,159	-1,021	6,191	3,311	2,879	3,901	0.63
Average	**5,969**	**-468**	**5,424**	**2,834**	**2,590**	**3,057**	**0.52**

a. Net change from the start (May 1) through the end (April 30) of each water year

b. Includes 1,233 mt/yr to account for atmospheric deposition

c. Difference between load in and load out

d. Difference between net change in lake content and net load (positive value is adsorption from water column)

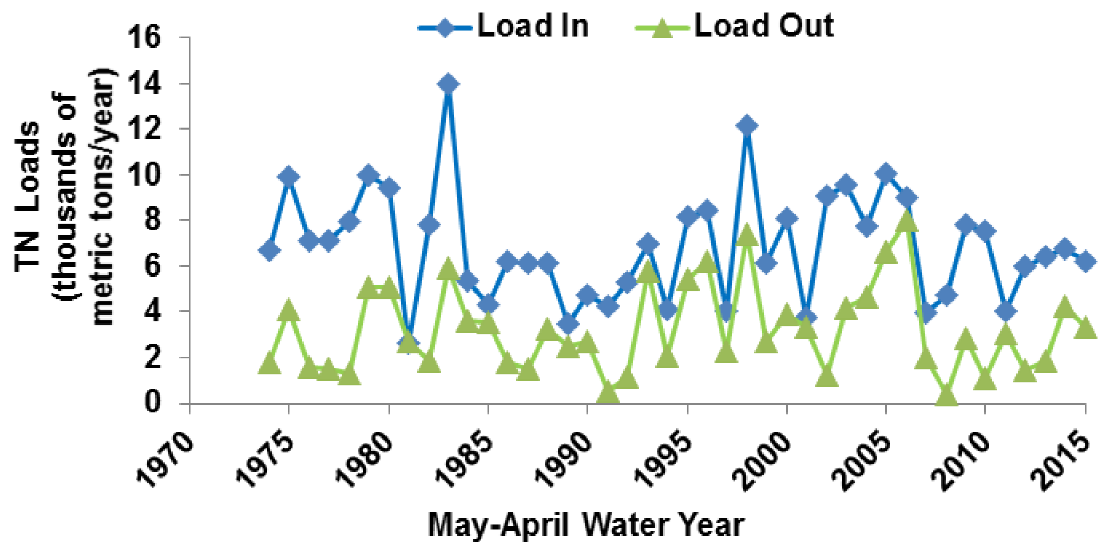


Figure 8-11. Timeline of water year inflow and outflow nitrogen load to and from Lake Okeechobee calculated from the lake nitrogen budget.

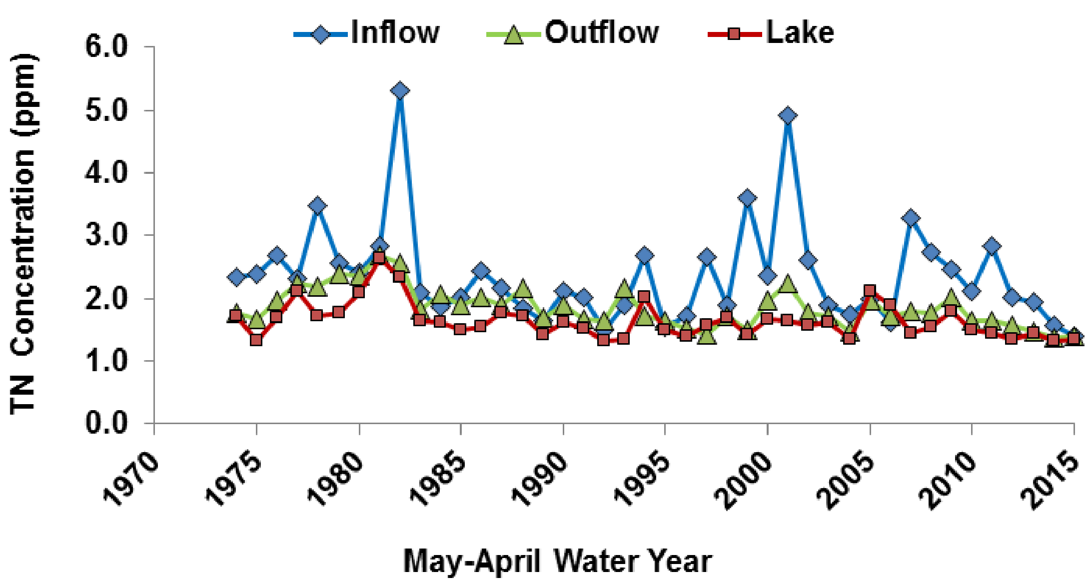


Figure 8-12. Timelines of inflow, outflow, and lake average TN concentrations calculated from the lake nitrogen budget.

LAKE OKEECHOBEE MONITORING RESULTS

SUBMERGED AQUATIC VEGETATION

SAV abundance, a key indicator of the lake's overall ecological health, has been routinely monitored on Lake Okeechobee since WY2000. SAV is sampled in two ways that vary in temporal and spatial scale. On a yearly basis, the entire nearshore and marsh zones of the lake are mapped to determine the spatial extent of each SAV species. On a quarterly basis, SAV is sampled at a subset of these annual sites in the south, west, and north nearshore zone. Further details of current methods and sampling sites are presented in the 2012 and 2013 SFER – Volume I, Chapter 8 (Zhang and Sharfstein 2012 and 2013, respectively).

Annual Mapping

In August of WY2011, the 1-km^2 nearshore sampling grid was extended into the marsh to incorporate SAV present in this habitat as well (**Figure 8-13**). This resulted in an additional 357 sites, for a potential grand total of 985 sampling sites. Because only nearshore sites were sampled prior to WY2011, the spatial extent of SAV for the nearshore sites are reported separately from the SAV coverage for the marsh sites to maintain consistency.

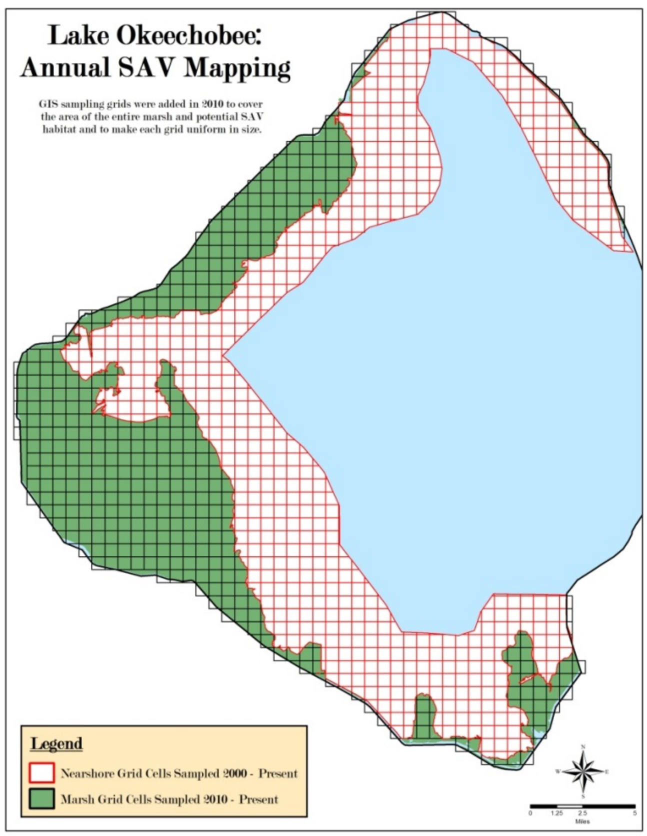


Figure 8-13. Map showing the geographic areas defined as nearshore (628 grid cells) and marsh (357 grids cells) SAV sites. The grid cells outlined in red are the nearshore grid cells that have been sampled since WY2001. The grid cells outlined in black are the marsh grid cells that were added in WY2011. Grid cell size = 1 km^2.

Nearshore Results

Areal coverage of SAV in the nearshore region over the past two years, as measured in August of each year, decreased by less than 2,000 ac (810 ha) with total acreage going from 33,854 ac (13,700 ha) in WY2014 to 31,877 ac (12,900 ha) in WY2015 (**Figure 8-14**). Lake stages during the three months prior to the August sampling were similar between the water years even though the stage at the time of sampling was 1.46 ft (0.445 m) higher in WY2014. In general, recent lake levels have been in the preferred stage envelope of 12.5 to 15.5 ft (3.81 to 4.72 m) and conditions have been favorable for growth. Over the past seven years, SAV areal coverage has been greater than 30,000 ac (12,140 ha) but only on two occasions (WY2010 and WY2013) did the total acres of SAV meet the Restoration Coordination and Verification Program (RECOVER) performance measure of greater than 40,000 ac (16,187 ha). Both of those water years were preceded by or during low lake stage conditions.

On an individual species basis in WY2015, muskgrass (*Chara* spp.), hydrilla *(Hydrilla verticillata)*, and pondweed (*Potamogeton* spp.) increased in areal coverage, while bladderwort (*Utricularia* spp.), tape grass (*Vallisneria americana*), and hornwort (*Ceratophyllum* spp.) declined. Coverage of southern naiad (*Najas guadalupensis* remained the same in both water years (**Figure 8-15**). The vascular species were dominated by *H. verticillata* (12,602 ac, 5,100 ha) followed by *Utricularia* spp. (9,637 ac, 3,900 ha), *Ceratophyllum* spp. (8,649 ac, 3,500 ha), *V. americana* (2,965 ac, 1,200 ha), *Potamogeton* spp. (2,224 ac, 900 ha), and *N. guadalupensis* (2,224 ac, 900 ha). In WY2015, **v**ascular species accounted for 67 percent of the total acres of SAV compared to 75 percent in WY2014. The metric that at least half of the total acreage be comprised of vascular species was met in both water years. Although the non-vascular *Chara* spp. covered 10,626 ac (4,300 ha) in WY2015, accounting for 33 percent of the total acres of SAV compared to 25 percent in the previous water year, its areal coverage has decreased significantly since WY2012 when it covered over 27,000 ac (10,926 ha). Water levels in WY2012 were extremely low (10.26 ft NGVD29 at the time of sampling) providing exceptional light conditions for *Chara* germination and growth. Water levels over the past two water years have been much higher (15.72 and 14.26 ft NGVD29 at the time of sampling in WY2014 and WY2015, respectively) resulting in less favorable growing conditions.

A number of shifts in species distribution have also occurred over the past few water years. The *Vallisneria* beds that had been present along the southwestern shoreline since the WY2009 surveys have diminished and were not evident in the most recent mapping effort. *Utricularia* spp., which was the dominant vascular species in WY2014, showed the biggest decrease in coverage, mostly in Fisheating Bay. Encouragingly, approximately 1,000 ac (404 ha) of *Potamogeton* were found in the southern end of the lake—the highest coverage reported in this area during annual mapping since before the hurricanes of WY2005.

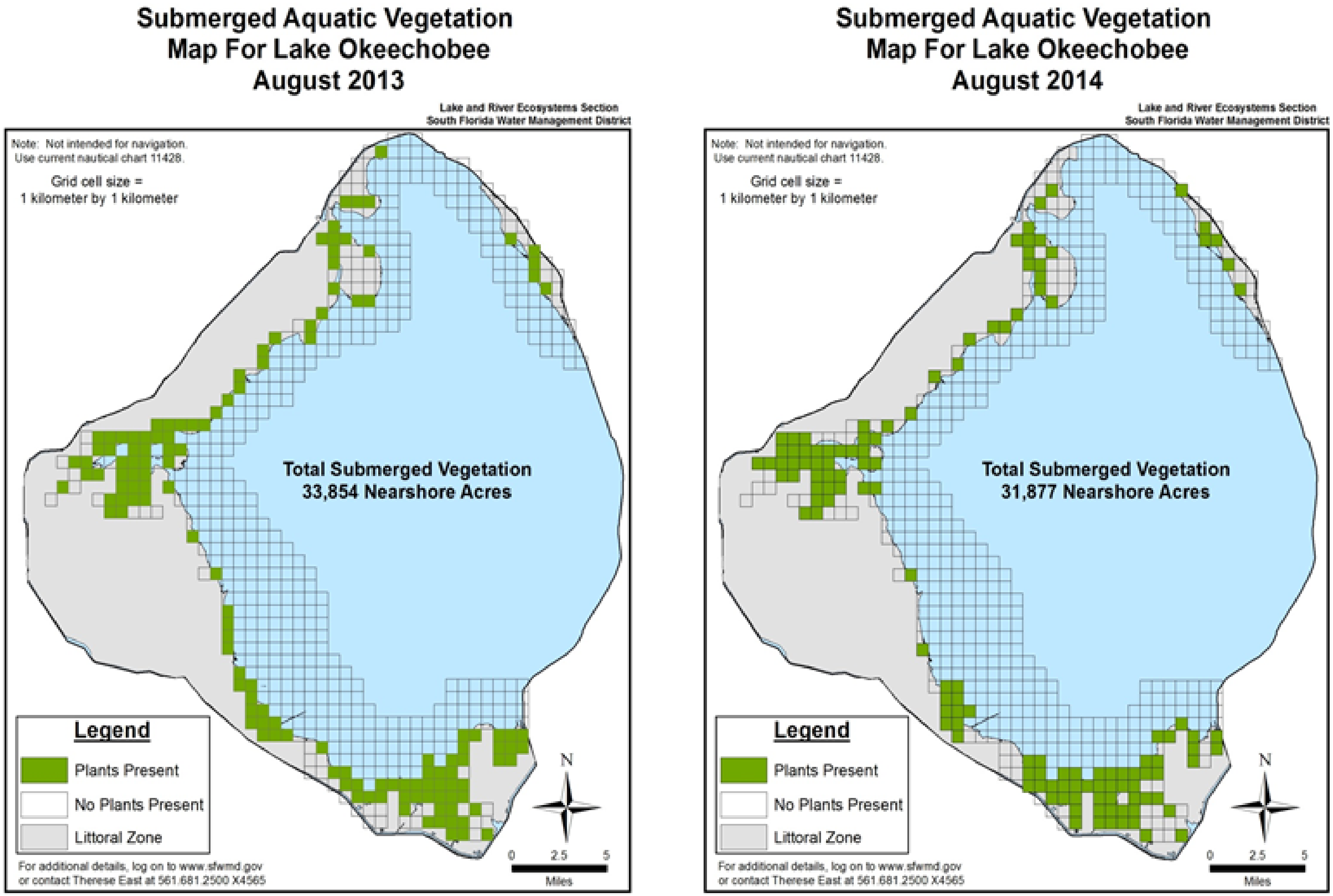


Figure 8-14. Annual nearshore SAV mapping results for WY2014 and WY2015.

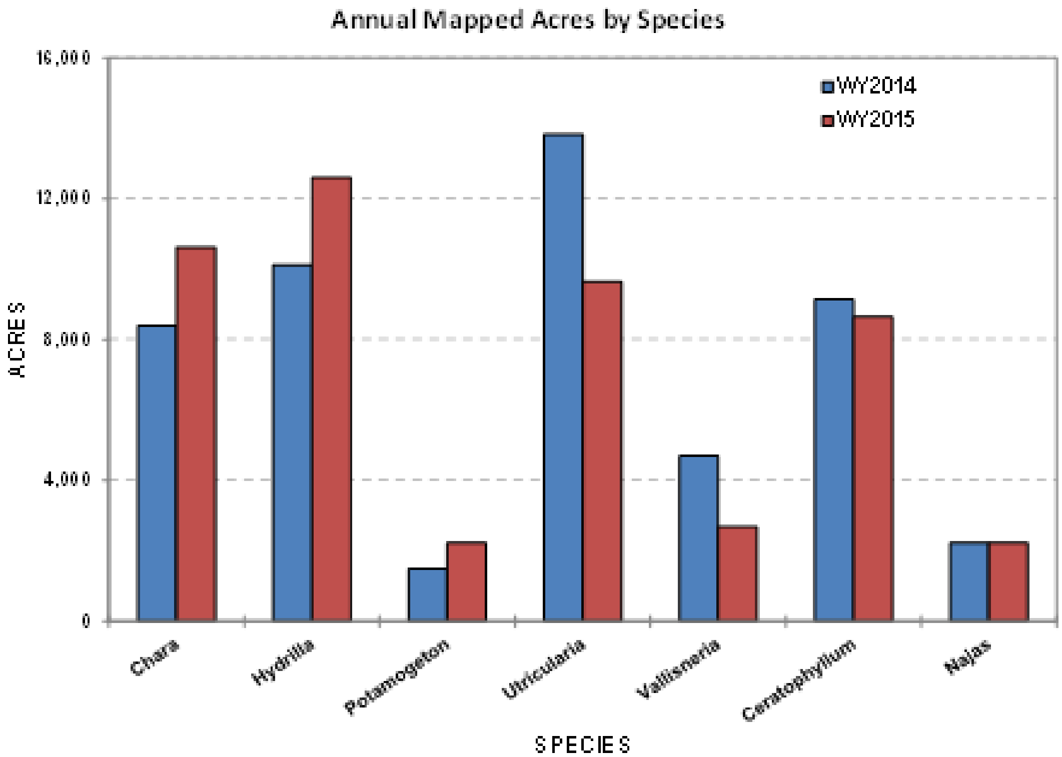


Figure 8-15. Total nearshore acres for each SAV species for WY2014 and WY2015. Vascular species include *Hydrilla verticillata*, *Potamogeton* spp., *Utricularia* spp., *Vallisneria americana*, *Ceratophyllum* spp., and *Najas guadalupensis*. *Chara* spp. is the only non-vascular species. Sampling was conducted in August of each year.

Marsh Results

Although SAV mapping in the marsh began in WY2011 and there were over 11,000 ac (4,450 ha) of SAV present, lake levels were so low in WY2012 and WY2013 that the marsh was dry and inaccessible. The higher lake stages in WY2014 and WY2015 allowed for sampling at many more marsh grids and total marsh SAV acreages were 27,923 ac (11,300 ha) and 18,533 ac (7,500 ha), respectively. Most of the decrease in coverage over the past year was seen in the extreme interior of the western marsh close to the Herbert Hoover Dike. Additionally, and in contrast to the WY2011 sampling effort, sites that were not navigable by boat were visited by helicopter in WY2014 and WY2015 to allow a better estimate of how much total potential habitat exists in the very interior areas of the marsh. Observations made from the air confirmed the assumption that many of the interior marsh grid cells primarily consisted of woody or terrestrial vegetation but also often had ponds that contained SAV. *Utricularia* spp. was the dominant SAV species in the marsh and accounted for 57, 82, and 83 percent of the SAV community in WY2011, WY2014, and WY2015, respectively.

The higher lake stages during the past two summers uprooted cattail (*Typha* sp.) along the littoral fringe of the western marsh, but SAV has not colonized this newly created available habitat. No reduction occurred in the approximately 7,000 ac of EAV in the south end of the lake that was formerly SAV habitat, but sparse beds of *Chara* and *Utricularia* spp. continue to thrive in the pockets of open water in this area.

Quarterly Mapping

Methodological Modifications

In WY2012, the quarterly sampling method was changed from sampling along 16 transects to sampling a subset of annual mapping grid cells. This change was made to reduce the sampling effort, make the quarterly data comparable to the annual data, and offer more informative data to stakeholders. As the sites and the sampling techniques were identical in both the annual and quarterly mapping efforts, data can be extracted from past annual mapping efforts and SAV distribution and relative abundance can be compared over time. Further details are presented in the 2013 SFER – Volume I, Chapter 8 (Zhang and Sharfstein 2013).

The 54 grid cells that were chosen bracketed the southern, western, and northern nearshore zones and spanned lake stages typical of the Lake Okeechobee Regulation Schedule 2008 (LORS2008) that is currently in effect. However, after sampling these 54 grid cells for three full years it became apparent that a number of these cells were more representative of emergent marsh habitat rather than nearshore SAV habitat. Also, at lake stages lower than approximately 12.0 ft (3.66 m) NGVD29, sites were too dry to sample or to support SAV. In February WY2015, the grid cell selection was reevaluated and a subset more representative of nearshore habitat was chosen**.** **Figure 8-16** shows the location of the current subset of 44 quarterly grid cells in relation to both the previous subset of 54 quarterly grid cells and to the original 16 quarterly transects. Yearly comparisons of SAV distribution and relative abundance of these 44 grid cells can be made in the same manner as stated above.

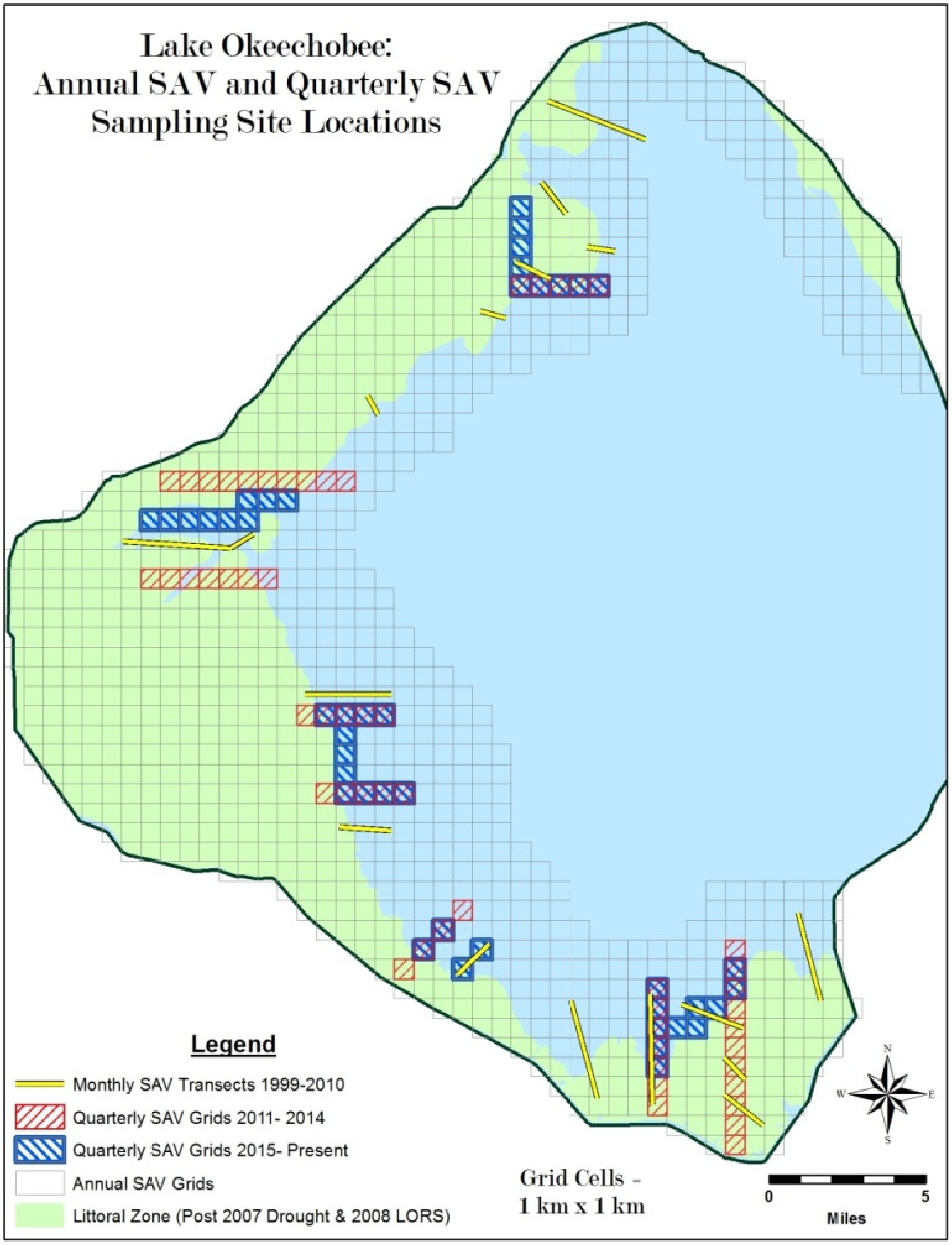


Figure 8-16. Change in SAV quarterly mapping locations over the 14-year sampling period. Both the 44 current (blue crosshatch) and the 54 previous (red crosshatch) grid cell sites are a subset of the annual mapping grid (grid cell size = 1 km^2). The 16 transects sampled prior to 2011 (WY2012) are depicted by yellow lines.

Results

Results from the quarterly grid mapping show a pattern similar to the annual nearshore results with a slight decline in numbers of sites with plants over the past two years and a larger decline compared to WY2013 (**Figure 8-17**). The slight decline in number of sites with plants seen between the WY2015 summer and winter sampling events is due to a loss of *Chara* sp. in the southern nearshore region (**Figure 8-18**). This is a typical seasonal pattern for SAV in Lake Okeechobee as *Chara* is easily uprooted during windy winter cold fronts. *Chara* densities generally increase slowly over the spring and summer months, peak in late August, then slowly declines through the winter months. The disappearance of the SAV beds (primarily *Vallisneria)* along the southern shoreline is also evident from the WY2015 summer and winter maps.

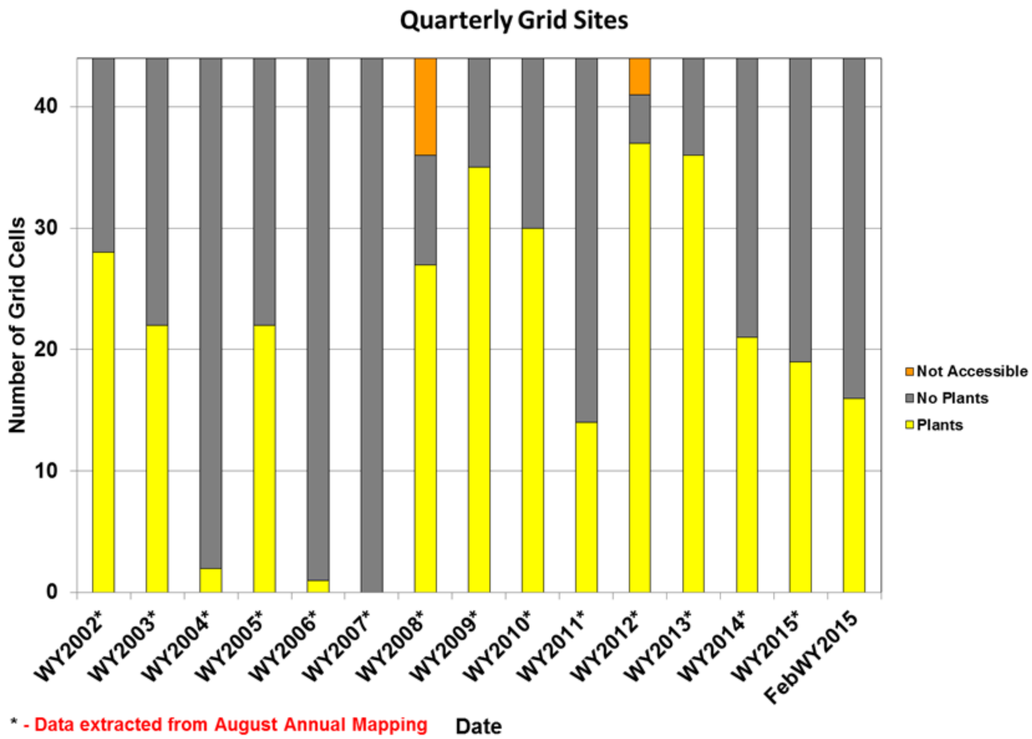


Figure 8-17. Number of grid cells with plants, without plants and that were inaccessible (dry, or too much terrestrial or emergent vegetation) for the 44 sites on an annual basis from WY2002–WY2012 (data from the August annual mapping grid cells) and in February of WY2015.

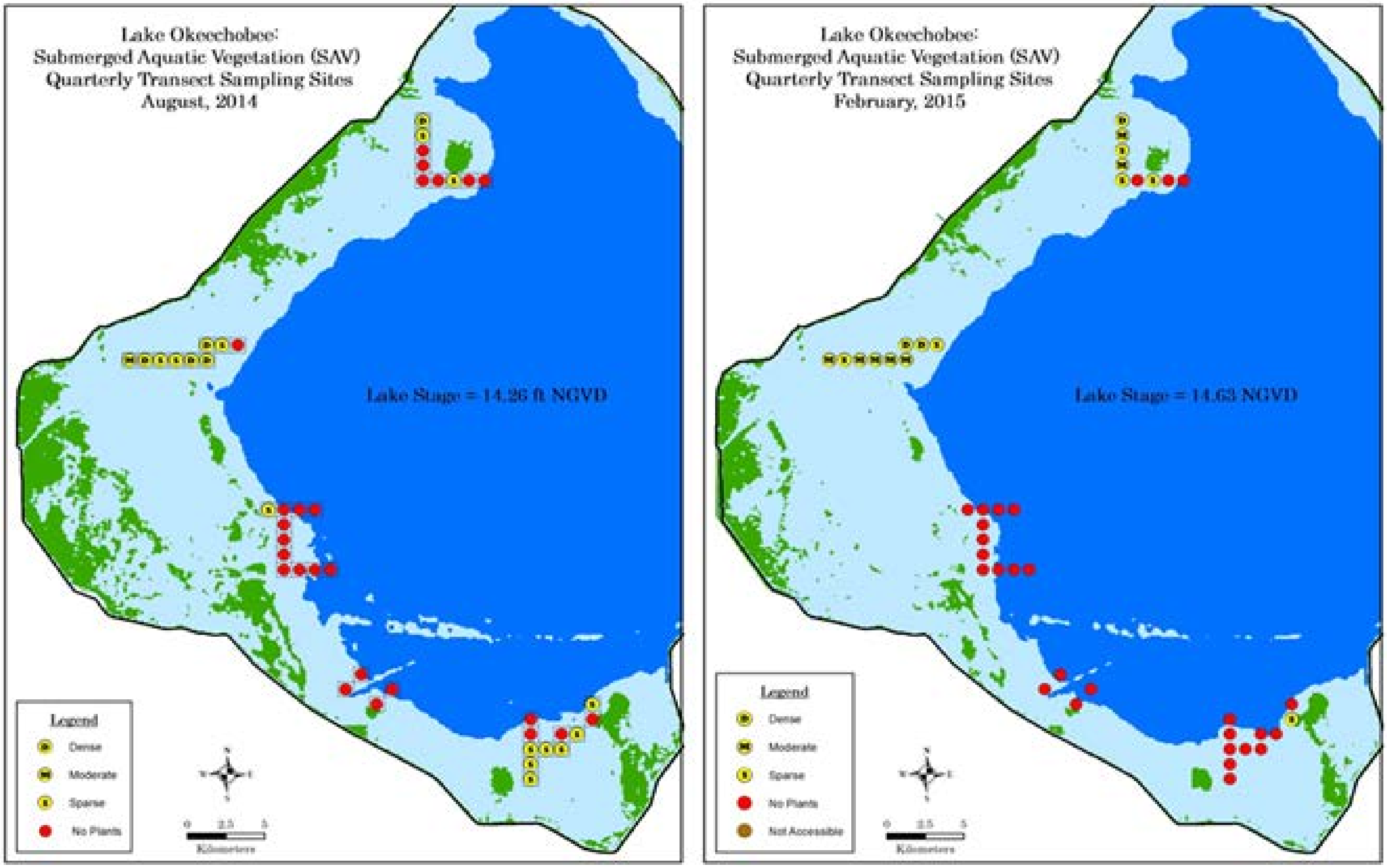


Figure 8-18. Quarterly mapping results for August 2014 and February 2015. The August data were extracted from the annual mapping grid cells.

EMERGENT VEGETATION

Vegetation Mapping

The emergent marsh in Lake Okeechobee provides important habitat for fish, wading birds, and other wildlife. The composition, distribution and areal coverage of the plant communities in the marsh are strongly influenced by hydrologic conditions, vegetation management actions, and competition between species, especially when native habitats are impacted by invasive exotic plants. To document and quantify how Lake Okeechobee's emergent marsh community responds to variable hydrologic conditions, management activity, and species competition, detailed vegetation maps showing the dominant and subdominant plant communities in the marsh are being created. Because of the vast size of Lake Okeechobee's marsh (> 40,000 ha) it is not feasible to map the entire marsh annually. Therefore, in years when the entire marsh is not mapped, plant communities are being mapped at sentinel sites. The sentinel sites consist of upper, mid and lower elevation plant communities, are considered representative of the entire marsh, and provide a means to detect and quantify spatial and temporal changes in plant communities (wildlife habitat) that occur in response to changing environmental conditions.

Temporal changes in the littoral landscape were evaluated by comparing the dominant plant communities observed within the same 1,170 1-ha grids in June 2014 and June 2015. Hydrologic conditions strongly influence plant community distribution and abundance in the marsh, although there often will be a lag in the plant community's response to changing conditions. Thus, antecedent hydrologic conditions were evaluated for the five month period (January 1–May 31) that preceded the June plant and habitat evaluations. In 2014, lake stage remained below 13.5 ft (4.11 m) NGVD29 for 34 percent of the time and never exceeded 14.49 ft (4.42 m) NGVD29. As a result, portions of the upper marsh were never inundated. In comparison, lake stage remained above 14.49 ft (4.42 m) NGVD29 for 49 percent of the time during the same five-month period in 2015. The higher lake stages inundated all the upper marsh and flooding depths in the mid and lower marsh were generally greater in 2015 compared to 2014 (**Figure 8-19**).

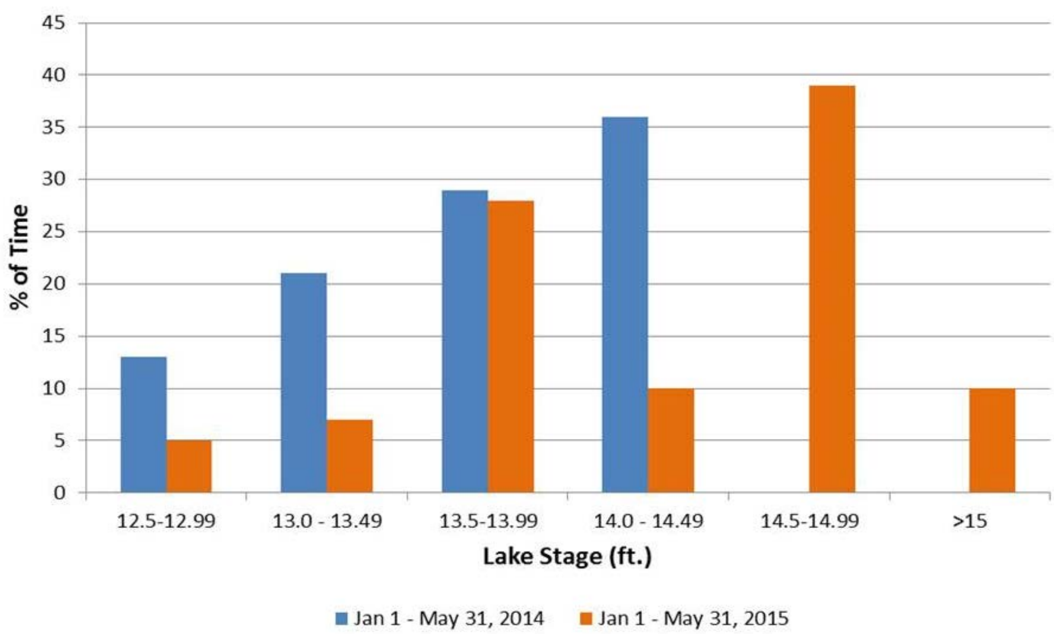
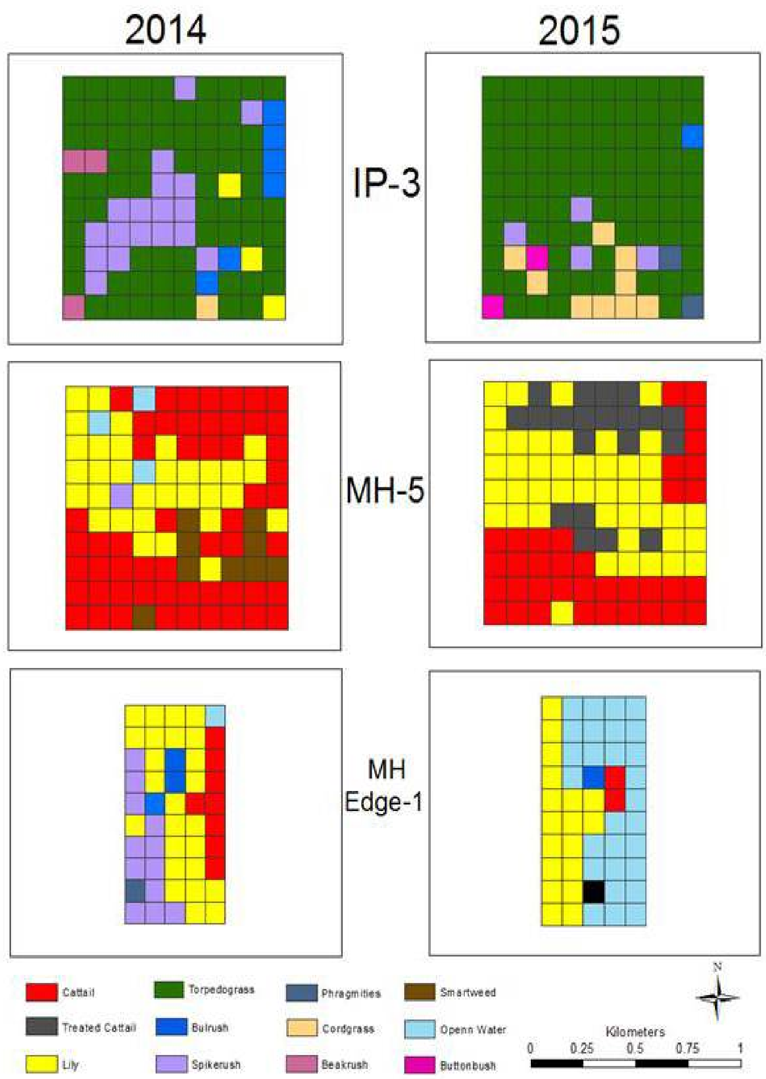


Figure 8-19. Lake stage recorded at LZ40 during the five-month periods from January 1 through May 31, 2014 (blue bars) and January 1 through May 31, 2015 (orange bars).

In 2014, cattail was the dominant plant species in 229 of the 1,170 grids sampled. Cattail dominance increased to 26 percent of the total area in 2015 (309 grids). Most of the increase in cattail coverage occurred at interior marsh locations. Along the outer edge of the marsh, cattail coverage declined and was replaced mostly by open water (**Figure 8-20**). The loss of cattail and an increase in open water was likely due to wave action that uprooted some of the cattail and damage from herbicide spraying that targeted the floating exotic species often tangled in cattail.

Figure 8-20. Alligator sunning on a tussock consisting of uprooted and sprayed cattail along the outside edge of the marsh near Observation Island (photo by SFWMD, March 2015). [Note: In some areas, a wall of cattail greater than 100 m wide disappeared between 2014 and 2015.]

Following a large increase in the distribution of woody species in 2014, wetter conditions in 2015 resulted in a slight decline (8 grids) of woody species. Other species that became less dominant in 2015 included water lily (*Nymphaea* sp. and *Nelumbo lutea*), pickerelweed (*Pontederia cordata*), arrowhead (*Sagittaria lancifolia*), spikerush (*Eleocharis cellulosa*), and beakrush (*Rhynchospora sp*.). Some of the decline in these native species was due to an increase in the exotic species torpedograss (*Panicum repens*). Additionally, smartweed (*Polygonum hydropiperoides*), American cupscale (*Sacciolepis striata*), and maidencane (*Panicum hemitomon*) were not observed in 2015. Some of the described vegetative changes were observed at sentinel monitoring sites IP-3, MH-5, and MH Edge-1 (**Figure 8-21**).



Plant dominance (# of 1 ha grids)

Selected Species	2014	2015
Cattail	229	309
Torpedograss	199	246
Spikerush	108	74
Woody Shrubs	115	107
Pontedaria and Sagitteria	73	40
Open Water	34	71

Figure 8-21. Vegetation maps for three sentinel study sites (IP-3, MH-5 and MH-Edge-1) in Lake Okeechobee's littoral marsh. IP-3 and MH-5 consisted of 100 1-ha grids and MH-Edge-1 consisted of 50 1-ha grids. A total of 1,170 grids were evaluated throughout the marsh and the numbers of grids dominated by selected vegetation classes are shown in the inset table.

Cattail has aggressively expanded through much of the marsh during the past few years and replaced several thousand hectares of important open water and spikerush habitat that once defined Moonshine Bay (**Figure 8-22**). There are several possible and non-mutually exclusive reasons that may explain why cattail is expanding: (1) treatment efforts have been relatively limited over the last several years; (2) generally, lower lake levels are creating more hydrologically suitable cattail habitat; (3) the hurricanes and associated elevated water levels of the mid-2000s pushed large volumes of nutrient-rich pelagic zone water back into portions of the previously pristine, rain-driven western marsh stimulating rapid expansion of cattail (note that this is the area where much of the cattail expansion has occurred in recent years); and (4) the relative infrequency of higher lake stages coupled with storm-generated wind and wave activity over the recent past. A combination of conditions appears to be capable of uprooting large areas of cattail along the nearshore-littoral edge when they occur.

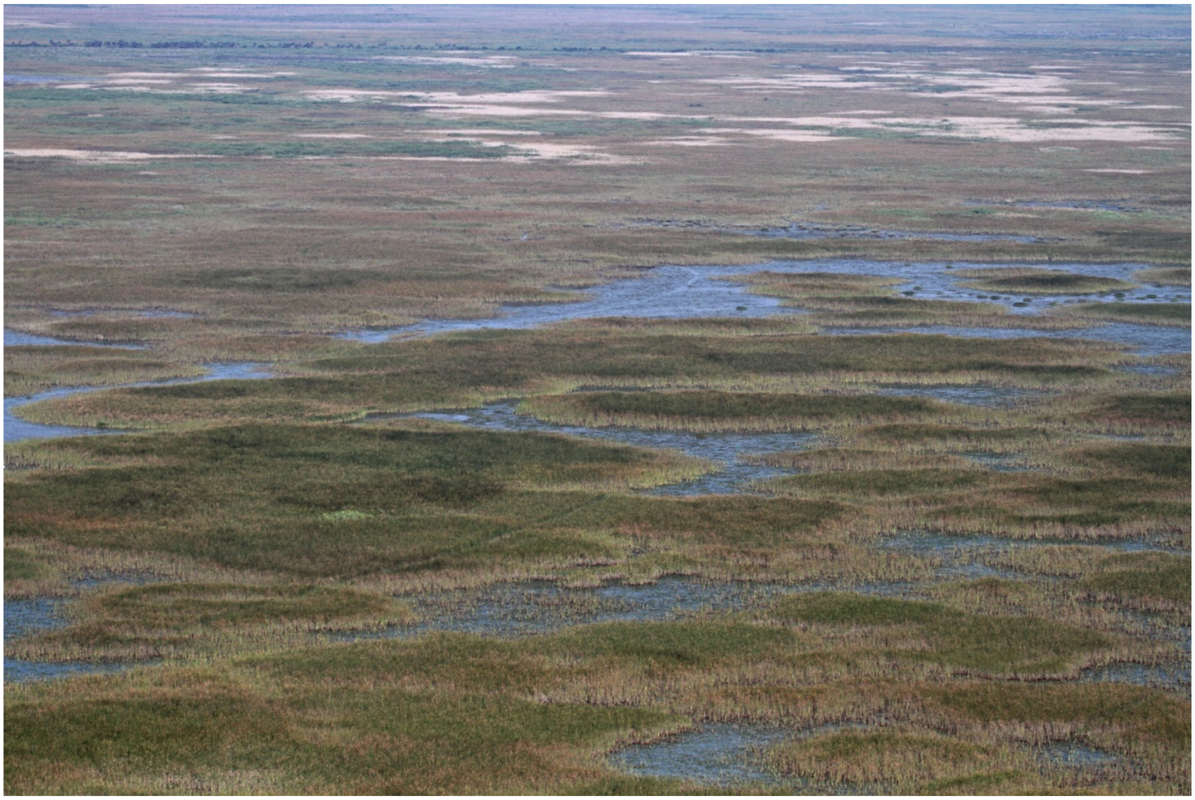


Figure 8-22. Cattail expansion on the western side of Moonshine Bay looking north (photo by SFWMD, April 2015). [Note: This area was previously dominated by spikerush.]

Approximately 75 ha of cattail were treated in Moonshine Bay in 2014 and nearly 1,300 ha are scheduled to be treated in the area in 2015. Some of the cattail treated in 2014 was burned to prevent the dead plant material from accumulating on the lake bottom and further degrading fish and wildlife habitat (**Figure 8-23**). FWC and the District will continue working together in 2015 to reduce cattail coverage and reestablish a mix of open water and desirable native plant habitat in Moonshine Bay. Cattail management in 2015 will again include a combination of herbicide treatments and prescribed burning.

All herbicides are applied according to label directions and none are classified as having direct adverse effects on wildlife. It is possible that herbicide application activities may have localized indirect temporary negative impacts on wildlife as a result of abrupt habitat shifts. However, many years of experience on Lake Okeechobee indicate that vegetation control activities produce overwhelming positive impacts on the ecosystem as a whole. The Lake Okeechobee Operating Permit requires that both herbicides and pesticides are monitored and reported in annual permit report. Therefore, this information is reported in the final 2016 SFER – Volume III, Appendix 4-1.

Annually fluctuating water levels and exotic and nuisance vegetation management lead to and support the development of a healthy and productive marsh. Annual monitoring and mapping of the dominant plant communities provides a quantifiable method to monitor and evaluate temporal changes that occur across the marsh landscape.

Figure 8-23. Treated cattail being burned in Moonshine Bay (photo by SFWMD, January 2015). Burning the cattail prevents the dead plant material from accumulating on the lake's bottom and further degrading fish and wildlife habitat.

EXOTIC SPECIES CONTROL PROGRAM

The Exotic Species Control Program has a requirement to identify the exotic species that threaten native flora and fauna within the Lake Okeechobee Watershed, and develop and implement measures to protect native species. The exotic plants and animals identified as threatening native species require management, or in the case of some animal species, monitoring to maintain awareness of possible future invasions.

The District's exotic and nuisance vegetation management program is designed to protect threatened native habitat in Lake Okeechobee and restore areas of the marsh that have been impacted by non-desirable species. Torpedograss is the most common emergent exotic plant in the lake's marsh and extensive efforts to reduce its coverage are ongoing. An evaluation of recent and historic torpedograss treatments dating as far back as 2010 indicated that several of the treatments provided excellent torpedograss control (greater than 90 percent), some for four years following a single treatment. Of the 12 treatment sites evaluated in 2015, control of torpedograss (treatment efficacy) was rated as 90 percent or greater at three sites, 50 to 89 percent at six sites, and less than 25 percent at three sites (**Figure 8-24**).

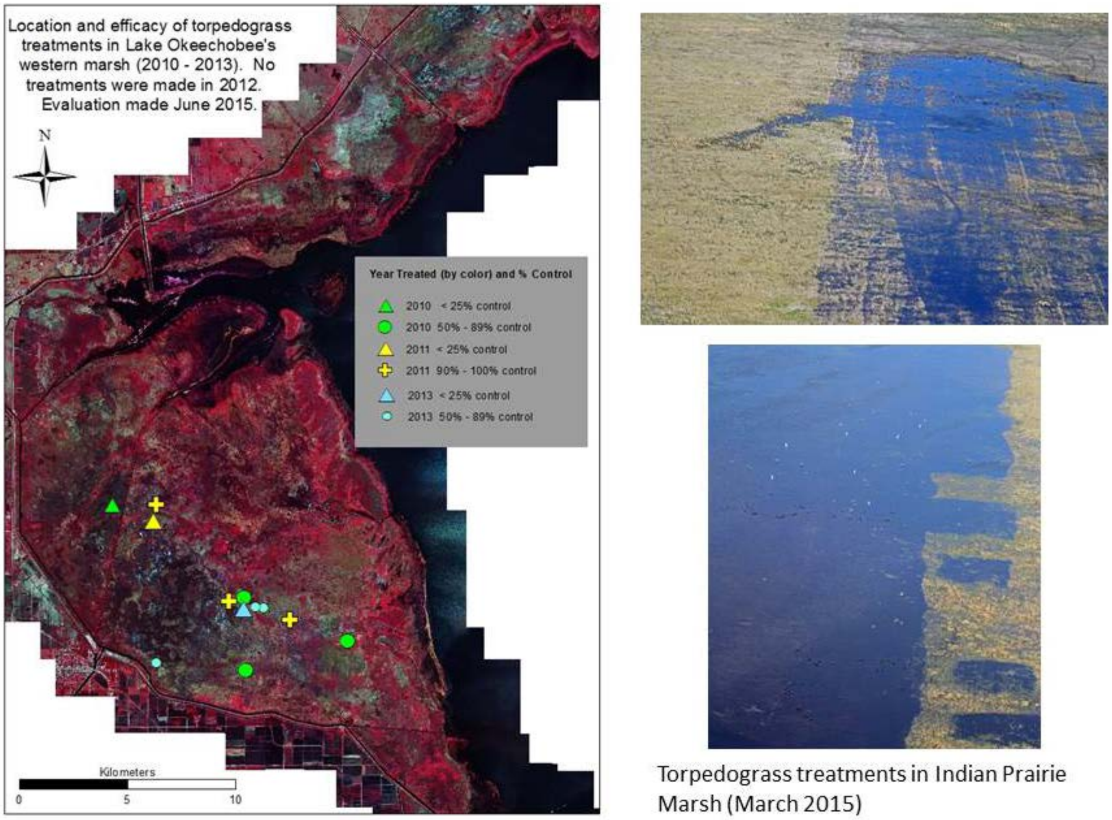


Figure 8-24. Location and efficacy of torpedograss treatments in Lake Okeechobee's western marsh (left panel; sites were evaluated in June 2015) and torpedograss treatment in Indian Prairie Marsh (right panels; March 2015).

During the past 12 months, treatment efficacy at the four evaluation sites treated in 2013 declined from greater than 90 percent control to 10 to 85 percent control. Efficacy remained high (90 to 100 percent control) at three of the four sites treated in 2011. Control at the fourth site dropped from moderate control (70 percent) in 2014 to poor control (20 percent) in 2015. One of the sites originally treated in 2010 was treated again in 2014 because torpedograss coverage exceeded 80 percent. Control was also poor (10 percent) at a second 2010 site and moderate (65 to 75 percent) at the remaining two sites.

Torpedograss treatments reduce the occurrence of dense monocultures of an exotic plant that provides limited habitat for wading birds, harvestable sport fish and other animals. When torpedograss is removed, native plants including spikerush, water lily, pickerelweed, and arrowhead commonly recolonize treated sites. Replacing torpedograss with shallow open water sites that include a mix of native vegetation can provide productive foraging habitat for wading birds and spawning and foraging habitat for fish. This was observed in a number of sites throughout the marsh during the 2015 wading bird survey (**Figure 8-25**).

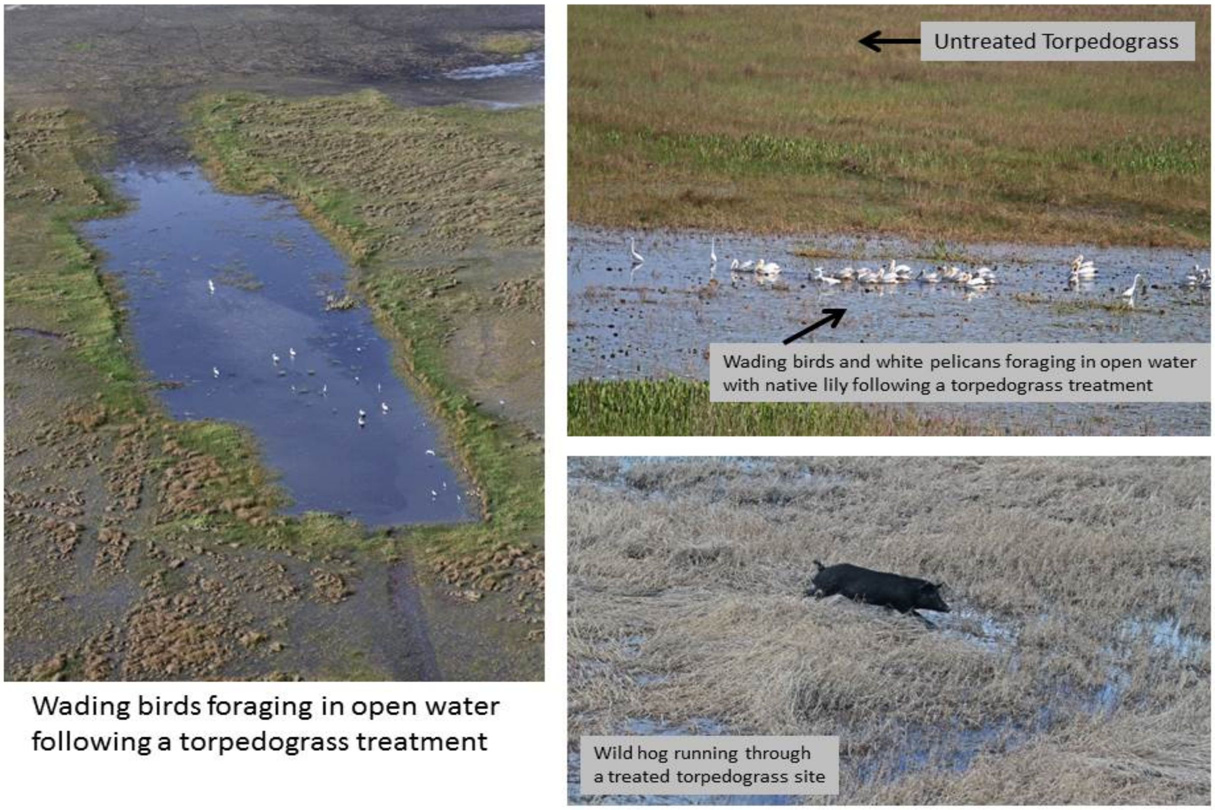


Figure 8-25. Wading birds foraging in open water with native vegetation following torpedograss treatments (left and upper right panels), and wild hog running through a treated torpedograss site in the Moore Haven marsh (lower right panel).

It is important to continue treating large acreages of torpedograss in Lake Okeechobee's interior marsh and infestations of torpedograss and exotic water grass (*Luziola subintegra*) that have recently established in productive fish habitat near the outer edge of the marsh. During the period from October 2013 through September 2014, 1,610 acres of torpedograss were treated. In addition, 718 acres of exotic water grass, 850 acres of cattail, and 41 acres of West Indian marsh grass (*Hymenachne amplexicaulis*) were also treated (**Figure 8-26**). In addition to emergent exotic and nuisance plant treatments, 2,503 ac (1,013 ha) of the floating exotic plant water lettuce (*Pistia stratiotes*) were treated.

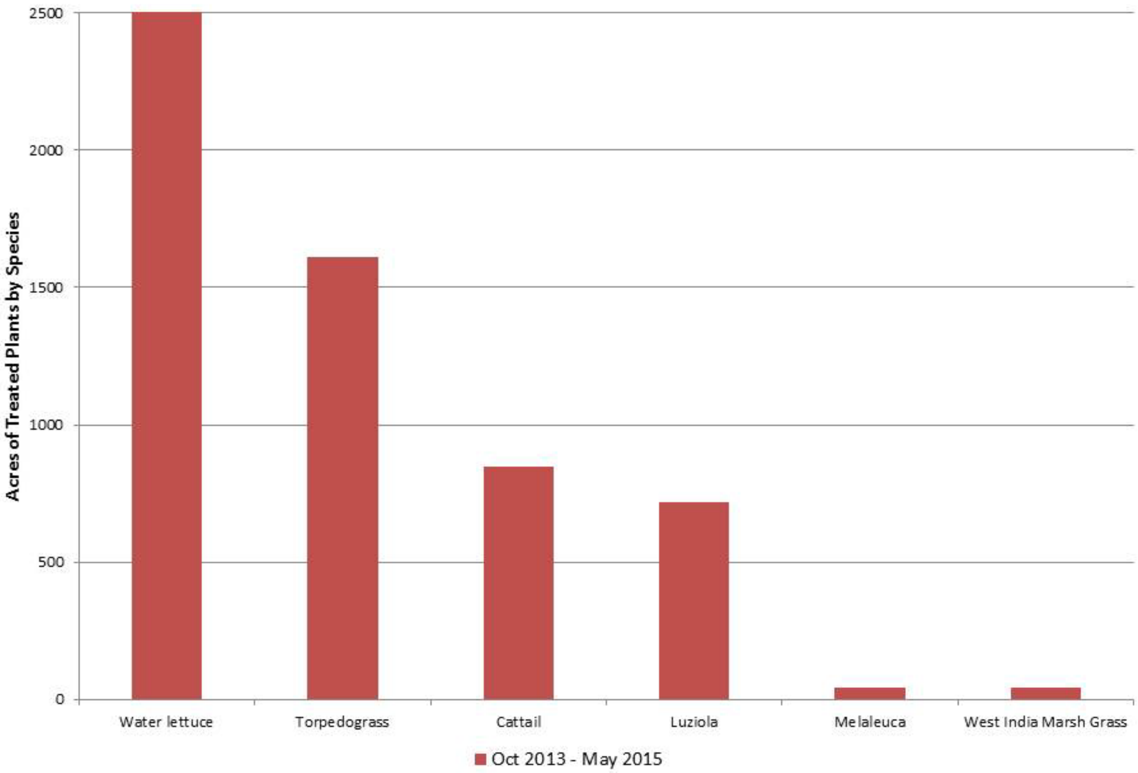


Figure 8-26. Number of acres of the most commonly treated exotic or invasive plants in Lake Okeechobee's western marsh. Treatments were conducted from October 2013 through May 2015.

ALGAL BLOOM MONITORING

Monthly Grab Sampling

Chla concentrations, indicative of phytoplankton densities, and microcystin-LR toxin concentrations, produced by some cyanobacterial blooms, were monitored on a monthly basis at nine nearshore sites from May 2004 (WY2005) through April 2012 (WY2012). In May WY2012, this sampling effort was combined with the agency's long-term water quality monitoring effort. Currently, bloom conditions are reported from ten nearshore and nine pelagic sites and microcystin toxin concentrations are reported from six of those same sites (**Figure 8-27**). Further details describing this relocation rationale are presented in the 2013 SFER – Volume I, Chapter 8 (Zhang and Sharfstein 2013).

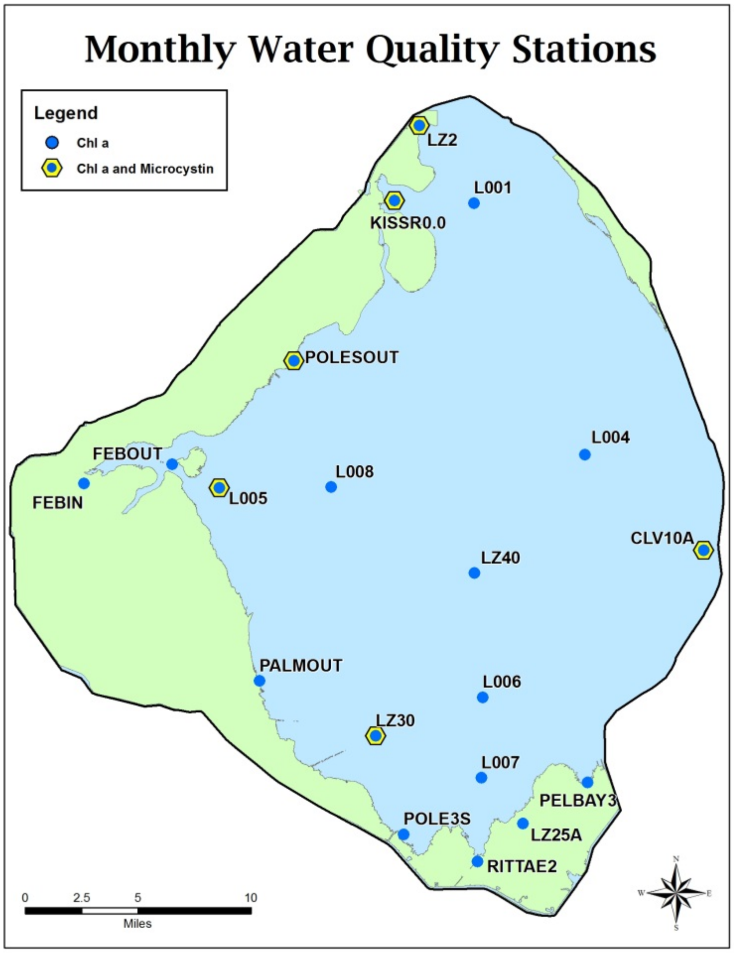


Figure 8-27. Nineteen algal bloom and six microcystin-LR toxin (yellow outline) sampling locations in Lake Okeechobee.

Algal bloom occurrences over the past two water years have increased compared to the previous two water years. In WY2012 and WY2013, there were a total of seventeen times when site specific Chla values exceeded the 40-ppb threshold that the District defines as algal bloom conditions, while during WY2014 and WY2015, site specific blooms occurred 44 and 33 times, respectively (**Figure 8-28**). In WY2014, 73 percent of the blooms occurred at nearshore sites and 27 percent occurred at pelagic sites. In WY2015, blooms occurred at the nearshore and pelagic sites 55 percent and 45 percent of the time, respectively. The highest frequency of blooms occurred at RITTAE2 in WY2014 with eight blooms. In that same water year, three sites along the western shoreline (L005, PALMOUT, and POLE3S) had bloom conditions seven times each. In WY2015, the highest frequency of blooms occurred at L005 (6 blooms), followed by Palm Out (5 blooms), and L008 and Poles Out with 3 blooms each. Over the past four water years, most of the blooms occurred at the southern and western sites. A few blooms occurred at the northern sites and no instances of blooms were reported at the eastern sites. From WY2012 through WY2015, bloom conditions occurred more frequently during the late summer and fall months but also occurred during spring (**Figure 8-29)**. The highest Chla concentration (142 ppb) occurred in June at L005 during WY2014. The second highest Chla value was 113 ppb in May WY2015 and it also occurred at L005. These values suggest moderate to severe bloom conditions.

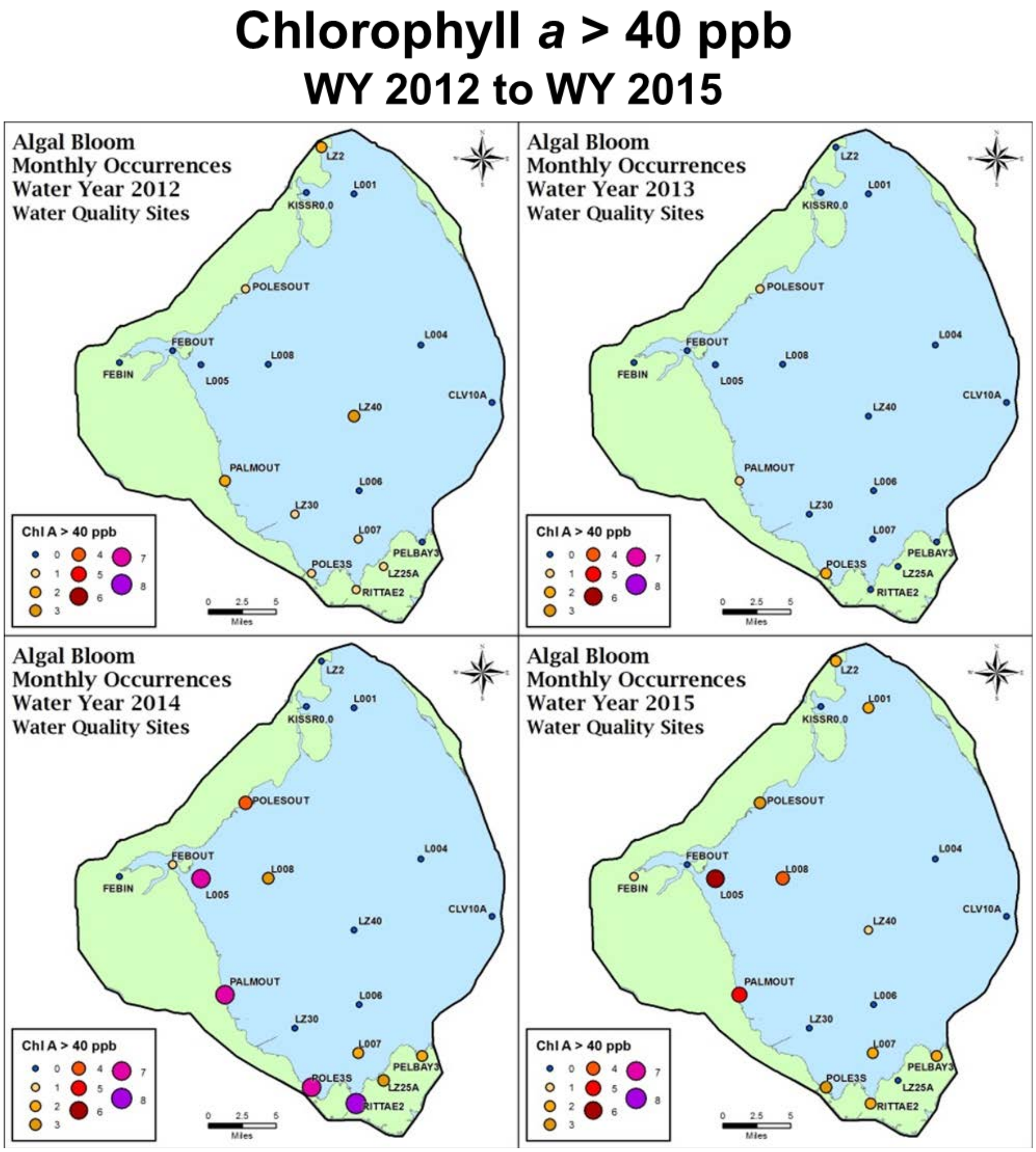


Figure 8-28. Frequency of blooms at the nineteen sites in Lake Okeechobee from WY2012 through WY2015. Chla concentration of > 40 ppb indicates bloom conditions.

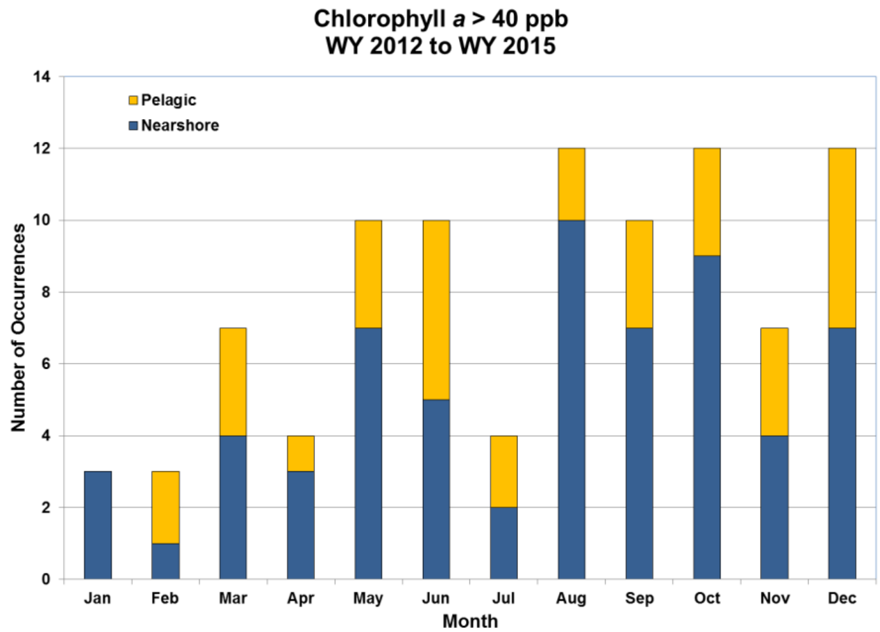


Figure 8-29. Frequency of blooms (Chla concentrations of > 40 ppb) by month for the 10 nearshore (blue bars) and 9 pelagic sites (gold bars) in Lake Okeechobee from WY2012 through WY2015.

Algal bloom proliferation generally results from a combination of environmental factors; including available nutrients, water temperatures, water column stability, light, and hydrology. Analysis suggests Chla concentrations in Lake Okeechobee were inversely correlated with dissolved inorganic nitrogen (DIN) concentrations (r = -0.45, $p < 0.0001$) and soluble reactive phosphorus (SRP) concentrations (r = -0.40, $p < 0.0001$), and positively correlated with TN concentrations (r = 0.45, $p < 0.0001$). Average DIN concentrations over the past two water years increased from 0.117 mg/L (range of 0.005 to 0.496 mg/L) to 0.130 mg/L (range of 0.001 to 0.444 mg/L) and average Chla concentrations decreased from 24.5 ppb to 19.8 ppb. Additionally, the four sites that had a high frequency (> 6) of bloom occurrences, L005, PALMOUT, POLE3S, and RITTAE2, had higher average Chla concentrations and lower average DIN and SRP concentrations compared to all of the other sites. In WY2014, the average Chla, DIN, and SRP values for the high bloom frequency sites were 51 ppb, 0.033 mg/L, and 0.007 mg/L, respectively while the averages for all the other sites were 17 ppb Chla, 0.140 mg/L DIN, and 0.042 mg/L SRP.

Microcystin concentrations at the six toxin sites in the 2012 and 2013 water years were low with averages across all sites of 0.14 µg/L and 0.13 µg/L, respectively. There were only two occasions in each of these water years when toxin concentrations exceeded the District's analytical detection limit of 0.2 µg/L. In WY2012, both instances occurred at the northern KISSR0.0 site and, in WY2013, one instance occurred at the southern LZ30 site and the other occurred at POLESOUT, a site along the northwest shoreline (**Figure 8-28**). Average microcystin concentrations increased in WY2014 and WY2015 to 0.20 µg/L and 0.25 µg/L, respectively. In contrast to the previous two water years, there were eighteen threshold exceedances in the last two water years, eight of them occurring in WY2014 and ten occurring in WY2015 (**Figure 8-30**). Over the past four years, nine of the twenty-two exceedances occurred at the northern KISSR0.0 site, and seven of the nine were in the last two years.

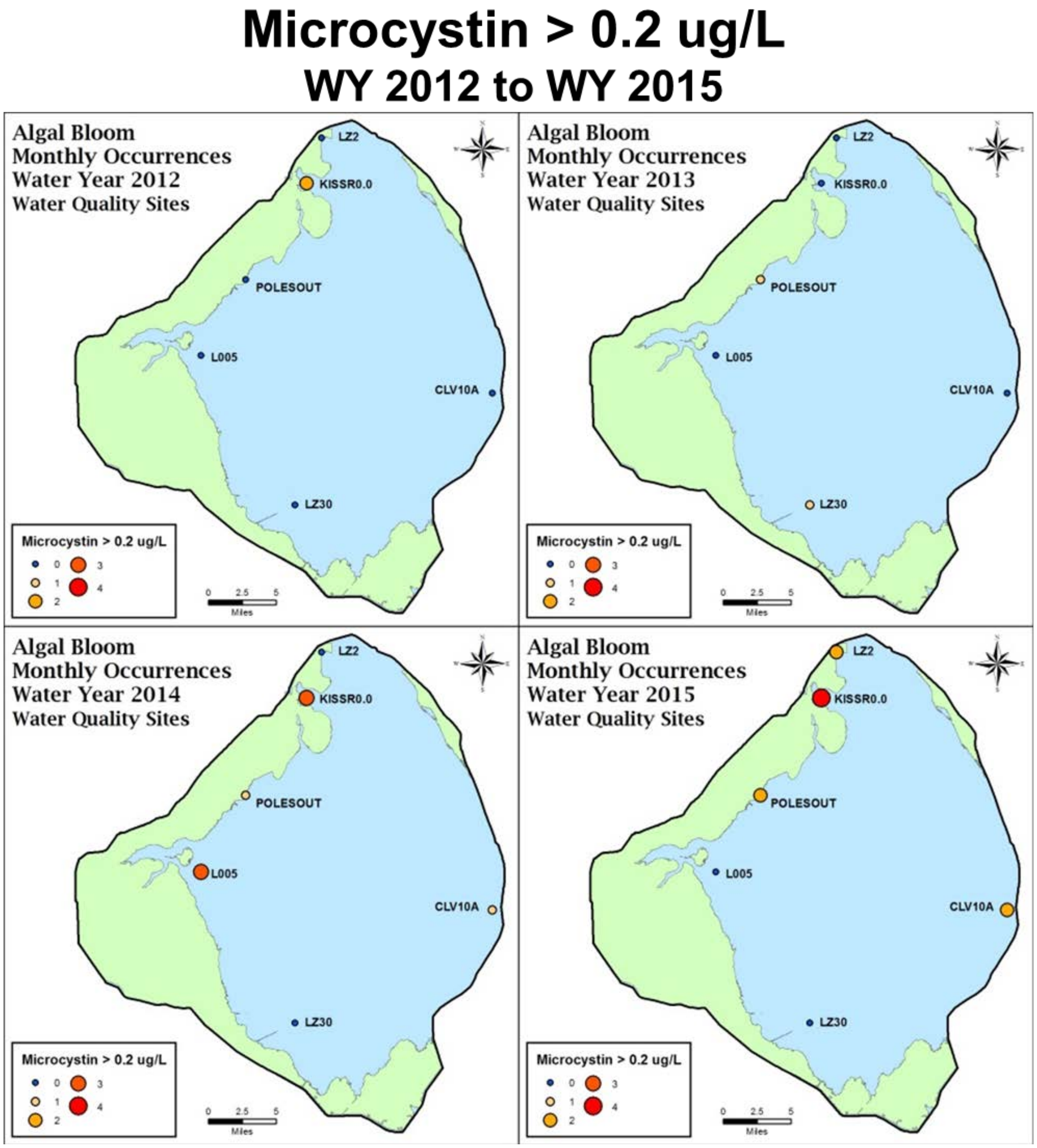


Figure 8-30. Frequency of microcystin concentrations that exceeded the analytical detection limit of 0.2 µg/L at the six toxin sites for WY2012 and WY2015.

The highest toxin value over the past four water years was reported at the easternmost site (CLV10A) in August WY2014 where toxin concentrations reached 2.2 µg/L. The second highest value (2.1 µg/L) was also reported from CLV10A exactly one year later. Even though CLV10A had the two highest toxin values, the concomitant Chla values were well below the bloom threshold value of 40 ppb, suggesting that there were blooms at this site prior to sampling but not during the sampling event. It is not clear what factors influence microcystin production in Lake Okeechobee as correlations have shown very weak relationships with inflows and temperature. In other Florida subtropical lakes, temperature does influence microcystin concentrations with the majority of elevated concentrations ($\geq$ 1.0 µg/L) occurring from May to November (Bigham et al., 2009). This pattern has also been seen in Lake Okeechobee over the past four water years (**Figure 8-31**).

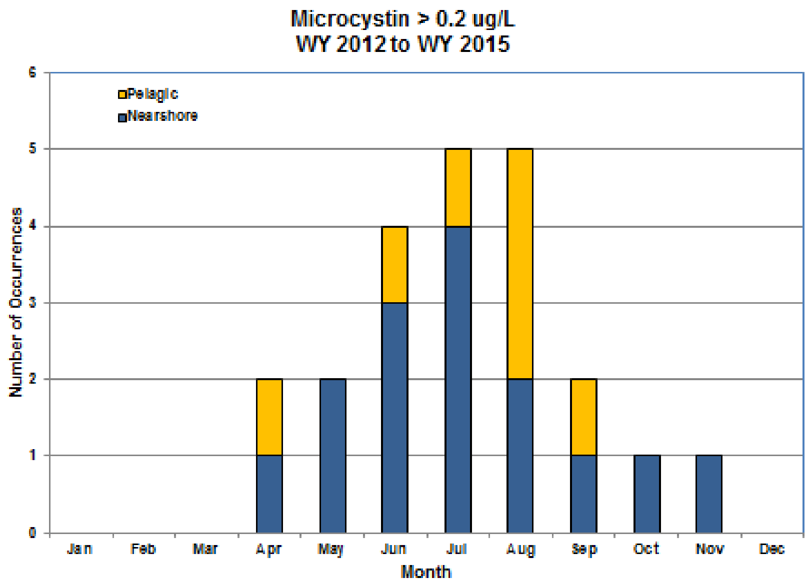


Figure 8-31. Frequency of microcystin concentrations exceeding the analytical detection limit of 0.2 µg/L by month for the three nearshore (blue bars) and three pelagic sites (gold bars) in Lake Okeechobee for WY2012 and WY2015.

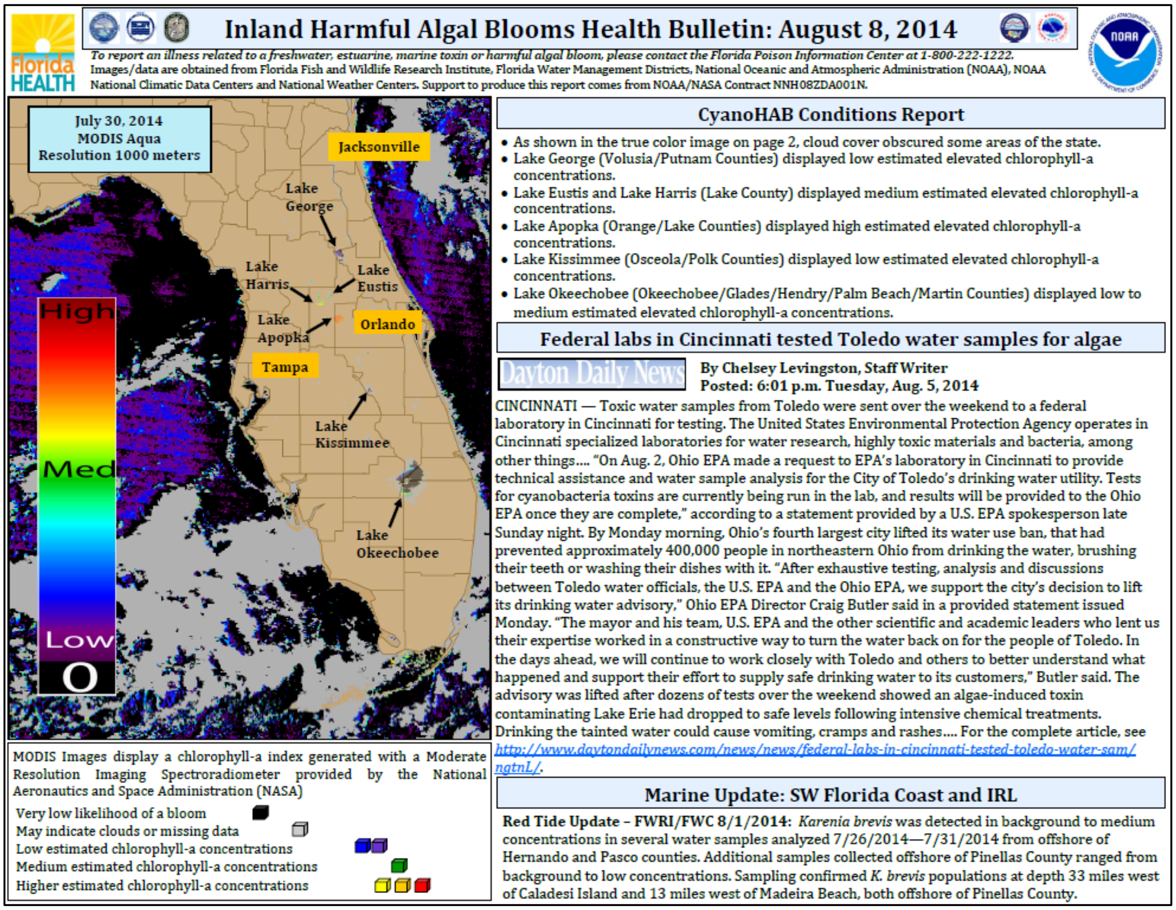
Although the average microcystin concentrations have gradually increased from 0.14 µg/L in WY2012 to 0.25 µg/L in WY2015, the maximum toxin value observed over the four water years (2.2 µg/L) was well below the recreational guidance value of 20 µg/L for activities in direct contact with water, and 100 µg/L for activities having indirect contact with water (Chorus and Bartram 1999). These guidance values represent a moderate probability of adverse health effects for humans. Over the past four to five years, the toxin values during the summer months have been surprising low given the relatively high Chla values, especially during isolated blooms. It has been suggested that shallow, eutrophic, subtropical systems have low microcystin to Chla ratios, which may explain the low toxin values. Additional research is needed to determine the reason for these results.

It should be noted that because the Lake Okeechobee algal bloom monitoring program is based on a finite number of stations sampled once monthly, it is primarily useful for providing an estimate of seasonal or annual trends. Algal blooms tend to be transient and ephemeral; therefore, the algal bloom monitoring program is in no way meant to be a comprehensive assessment of bloom or cyanotoxin events on Lake Okeechobee. The data presented above needs to be interpreted with these limitations in mind.

A more frequent, less time consuming and quicker determination of algal bloom conditions on Lake Okeechobee would allow for a more thorough understanding of bloom dynamics and might lead to information that would allow for the development of management strategies to prevent or disrupt the progress of ongoing blooms. The following section describes a project that has been implemented in an effort to address this capability.

Satellite Imagery for Algal Bloom Monitoring

The District has partnered with the National Oceanic and Atmospheric Administration's National Centers for Coastal Ocean Science (NCCOS) to evaluate using satellite imagery as a tool for frequently monitoring and forecasting algal blooms on Lake Okeechobee. NCCOS has developed a cyanobacteria bloom satellite image product which is being used to forecast blooms of the toxic cyanobacterium *Microcystis aeruginosa* in western Lake Erie. This product is also being provided by the Florida Department of Health as an indicator of potential cyanobacteria bloom conditions in Florida lakes and is distributed to lake managers via the Inland Harmful Algal Blooms Health Bulletin (**Figure 8-32**).



Inland Harmful Algal Blooms Health Bulletin: August 8, 2014

To report an illness related to a freshwater, estuarine, marine toxin or harmful algal bloom, please contact the Florida Poison Information Center at 1-800-222-1222.
Images/data are obtained from Florida Fish and Wildlife Research Institute, Florida Water Management Districts, National Oceanic and Atmospheric Administration (NOAA), NOAA National Climatic Data Centers and National Weather Centers. Support to produce this report comes from NOAA/NASA Contract NNH08ZDA001N.

MODIS Images display a chlorophyll-a index generated with a Moderate Resolution Imaging Spectroradiometer provided by the National Aeronautics and Space Administration (NASA)

Very low likelihood of a bloom
May indicate clouds or missing data
Low estimated chlorophyll-a concentrations
Medium estimated chlorophyll-a concentrations
Higher estimated chlorophyll-a concentrations

CyanoHAB Conditions Report

- As shown in the true color image on page 2, cloud cover obscured some areas of the state.
- Lake George (Volusia/Putnam Counties) displayed low estimated elevated chlorophyll-a concentrations.
- Lake Eustis and Lake Harris (Lake County) displayed medium estimated elevated chlorophyll-a concentrations.
- Lake Apopka (Orange/Lake Counties) displayed high estimated elevated chlorophyll-a concentrations.
- Lake Kissimmee (Osceola/Polk Counties) displayed low estimated elevated chlorophyll-a concentrations.
- Lake Okeechobee (Okeechobee/Glades/Hendry/Palm Beach/Martin Counties) displayed low to medium estimated elevated chlorophyll-a concentrations.

Federal labs in Cincinnati tested Toledo water samples for algae

Dayton Daily News **By Chelsey Levingston, Staff Writer**
Posted: 6:01 p.m. Tuesday, Aug. 5, 2014

CINCINNATI — Toxic water samples from Toledo were sent over the weekend to a federal laboratory in Cincinnati for testing. The United States Environmental Protection Agency operates in Cincinnati specialized laboratories for water research, highly toxic materials and bacteria, among other things.... "On Aug. 2, Ohio EPA made a request to EPA's laboratory in Cincinnati to provide technical assistance and water sample analysis for the City of Toledo's drinking water utility. Tests for cyanobacteria toxins are currently being run in the lab, and results will be provided to the Ohio EPA once they are complete," according to a statement provided by a U.S. EPA spokesperson late Sunday night. By Monday morning, Ohio's fourth largest city lifted its water use ban, that had prevented approximately 400,000 people in northeastern Ohio from drinking the water, brushing their teeth or washing their dishes with it. "After exhaustive testing, analysis and discussions between Toledo water officials, the U.S. EPA and the Ohio EPA, we support the city's decision to lift its drinking water advisory," Ohio EPA Director Craig Butler said in a provided statement issued Monday. "The mayor and his team, U.S. EPA and the other scientific and academic leaders who lent us their expertise worked in a constructive way to turn the water back on for the people of Toledo. In the days ahead, we will continue to work closely with Toledo and others to better understand what happened and support their effort to supply safe drinking water to its customers," Butler said. The advisory was lifted after dozens of tests over the weekend showed an algae-induced toxin contaminating Lake Erie had dropped to safe levels following intensive chemical treatments. Drinking the tainted water could cause vomiting, cramps and rashes.... For the complete article, see http://www.daytondailynews.com/news/news/federal-labs-in-cincinnati-tested-toledo-water-sam/ngtnL/.

Marine Update: SW Florida Coast and IRL

Red Tide Update – FWRI/FWC 8/1/2014: *Karenia brevis* was detected in background to medium concentrations in several water samples analyzed 7/26/2014—7/31/2014 from offshore of Hernando and Pasco counties. Additional samples collected offshore of Pinellas County ranged from background to low concentrations. Sampling confirmed *K. brevis* populations at depth 33 miles west of Caladesi Island and 13 miles west of Madeira Beach, both offshore of Pinellas County.

Figure 8-32. Algal Bloom Health Bulletin distributed by Florida Department of Health reporting bloom conditions in major waterbodies in the SJRWMD and in Lake Okeechobee. [Note: Data from Lake Okeechobee is currently being validated.]

Following a training session in February 2014, the District began collecting instantaneous surface reflectance data using an NCCOS above-water radiometer (a Satlantic Hypergun) at the monthly water quality/algal bloom monitoring stations in addition to the chlorophyll, toxin, and phytoplankton samples already being collected (**Figure 8-27**). Currently, NCCOS is analyzing the instantaneous surface reflectance data and comparing it to the corresponding moderate resolution imaging spectroradiometer (MODIS) cyanobacteria index (CI) imagery. An example of this comparison is shown in **Figure 8-33**. The CI being used to detect blooms in Lake Erie was applied to MODIS-aqua imagery on Lake Okeechobee on August 6, 2014. The CI is essentially a measure of the shape of the remote sensing reflectance curve centered at 681 nanometers (nm). A more negative shape (or decrease) at 681 nm indicates a higher concentration of cyanobacteria and is represented by the light blue to orange (warm) colors in the MODIS CI image (**Figure 8-33**, right side). Both the MODIS CI image and the field spectral scan at PALMOUT (**Figure 8-33**, left side; note decrease at 681 nm) indicated a cyanobacterial bloom. Field data also confirmed that bloom conditions (Chla > 40 ppb) occurred at PALMOUT, RITTAE2, L007, POLESOUT, and PELBAY3 and that a mixed cyanobacteria bloom, dominated by *Cylindrospermopsis raciborskii* and *Anabaena* spp., was present on August 6, 2014, in the western portion of the lake. Additionally, the microcystin concentration observed at LZ30 was 2.62 µg/L, which is above both the District's analytical detection limit of 0.2 µg/L and the FDEP analytical detection limit of 1.0 µg/L. These preliminary results show promise for satellite detection in Lake Okeechobee.

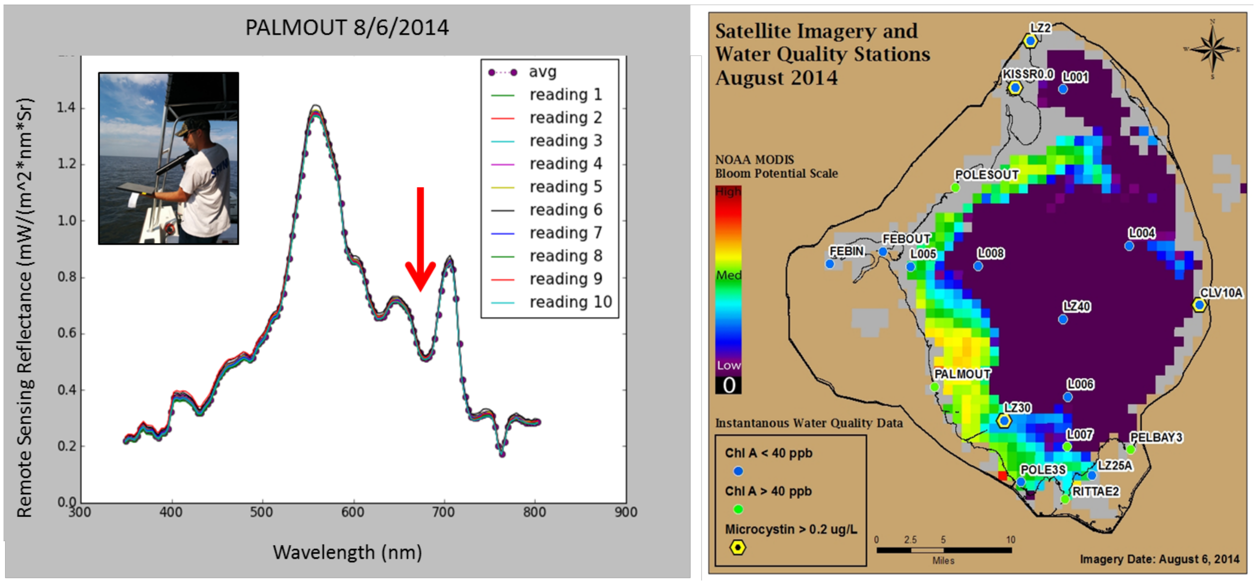


Figure 8-33. Reflectance data at PALMOUT (left) and MODIS CI image with Chla and microcystin data for Lake Okeechobee on August 6, 2014 (right). The magnitude of the decrease at 681 nm in spectral image on left (red arrow) translates into the relative magnitude of a cyanobacterial bloom and is represented by the light blue to orange colors on the MODIS image on the right.

Future analyses are planned to involve comparisons with the water quality data and bloom information to tease out the various contributions of sediment, dissolved pigments, Chla, and characteristics indicative of cyanobacteria (absorption and backscattering at specific wavelengths) to develop a satellite algorithm specific to Lake Okeechobee and other turbid lakes throughout the United States.

If successful, then this satellite technology has the potential to be a rapid, effective, and affordable option for monitoring blooms at lake-wide scale and their potential severity on a routine and near-real time basis. Additional potential uses for the imagery include (1) linking to current and future models (e.g., Lake Okeechobee Ecological Model) to allow predictions of bloom movements as is currently being done with Great Lakes data, and (2) providing algal bloom data for other District waterbodies that are large enough to be seen by the MODIS satellite (Lakes Istokpoga and Kissimmee for instance).

Satellite technology does have limitations including reduced image quality or the inability to collect images during periods of heavy cloud cover or sun glint and the lack of penetration below a few centimeters of the water's surface. The latter limitation does not allow the depth of bloom dispersal through the water column to be detected and, therefore, field observations will continue to be needed to fully describe blooms of interest. However, with the satellite tool targeted rather than hit-or-miss sampling of algal blooms could be done.

STATUS OF THE LAKE OKEECHOBEE FISHERY

Lake Okeechobee's fishery is monitored annually by the FWC. They use a standardized lake-wide electrofishing protocol to monitor the near shore fishery and a lake-wide trawling protocol to monitor pelagic species.

Electrofishing

Lake-wide electrofishing conducted at 22 nearshore sites during October 2014 resulted in the capture of 11,858 fish with a combined biomass of 1,172 kilograms. Forty-three species were represented in the catch. Five dominant species (more than 5 percent composition) collectively comprised 75 percent of the catch by number and were, in order of abundance: threadfin shad (*Dorosoma petenense*), eastern mosquitofish (*Gambusia holbrooki*), bluegill (*Lepomis macrochirus*), sailfin molly (*Poecilea latipinna*), and largemouth bass (*Micropterus salmoides*) (LMB). Seven dominant species collectively comprised 78 percent of the catch by weight and were, in order of biomass: LMB, bluegill, Florida gar (*Lepisosteus platyrhincus*), striped mullet (*Mugil cephalus*), bowfin (*Amia calva*), lake chubsucker (*Erimyzon sucetta*), and gizzard shad (*Dorosoma cepedianum*).

About 4,000 to 7,000 fish were collected annually between 2008 and 2013 (**Figure 8-34**). The large increase in the number of fish collected in 2014 (11,858) was mostly due to an increase in small forage fish including eastern mosquitofish and threadfin shad. The total fish biomass collected in 2014 increased by 255 kg compared to 2013. Reductions in common snook (*Centropomus undecimalis*) and Florida gar biomass were offset by increases in biomass of bluegill, redear, LMB, gizzard shad, lake chubsucker, and other species.

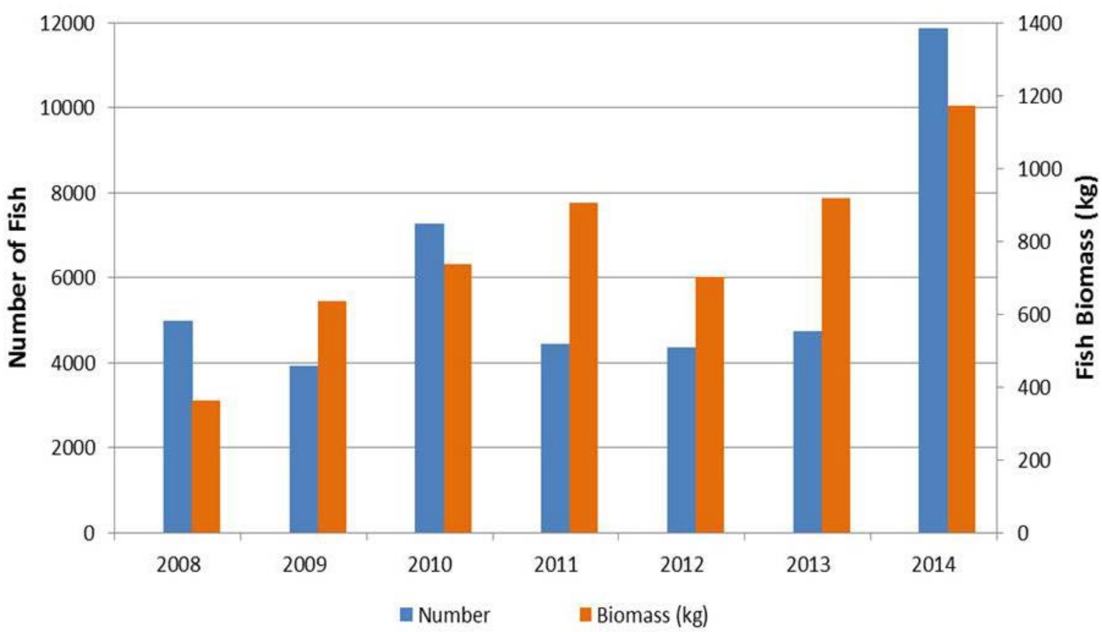


Figure 8-34. Lake-wide electrofishing data indicating the total number of fish (blue bars) and the total fish biomass (kg) (orange bars) collected October 2008–2014.

Temporal changes in the fish community, as indicated by changes in proportions of selected prey and predator species, were common in the nearshore fishery (**Figure 8-35**). Collectively, shad species and mosquitofish accounted for 69 percent of the total catch in 2008 but declined to 16 to 27 percent of the total catch in 2009–2011. Their abundance has again increased and accounted for 56 percent of the total catch in 2014. Due to the recent large increase in forage fish abundance, the portion of the total catch consisting of LMB and bluegill declined the past two years even though more fish of these two species were collected in 2014 compared to 2013.

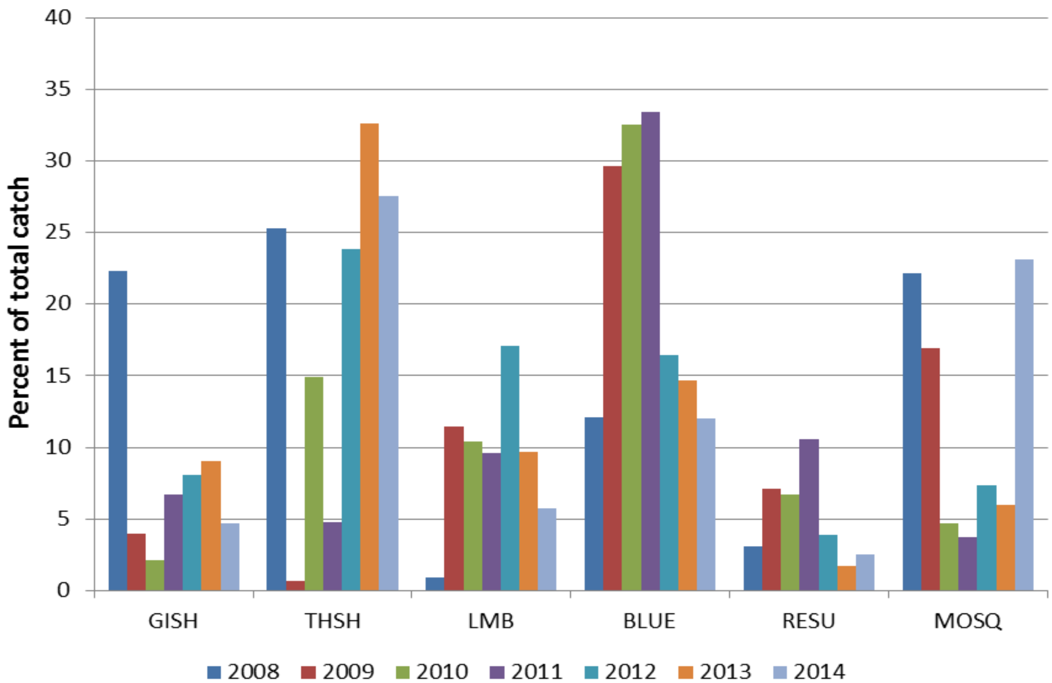


Figure 8-35. Percent of total catch of selected prey and piscivorous species collected by electrofishing October 2008–2014. [Note: GISH =gizzard shad, THSH = thread fin shad, LMB =largemouth bass, BLUE =bluegill, RESU = redear sunfish, and MOSQ = mosquitofish.]

In addition to fish abundance and biomass, the size and composition of the fish community can be evaluated using catch per unit effort (CPUE) data (**Figure 8-36**). Low catch rates were reported for LMB, bluegill, and redear sunfish from 2005 through 2008 following damaging hurricanes in 2004 and 2005 that impacted important fish habitat and food chain links. Catch rates for LMB have remained greater than 0.4 fish per minute since 2009, with small peaks in 2010, 2012, and 2014. Bluegill abundance increased in 2009 and has remained above the 2008 catch rate for the past six years. Catch rates for redear sunfish increased from 2009 through 2011, declined in 2012–2013, and then increased again in 2014. Gizzard shad abundance peaked in 2008, while the abundance of many piscivorous fish was relatively low. The catch rate for threadfin shad was lowest in 2009 and peaked to 3.3 fish per minute in 2014.

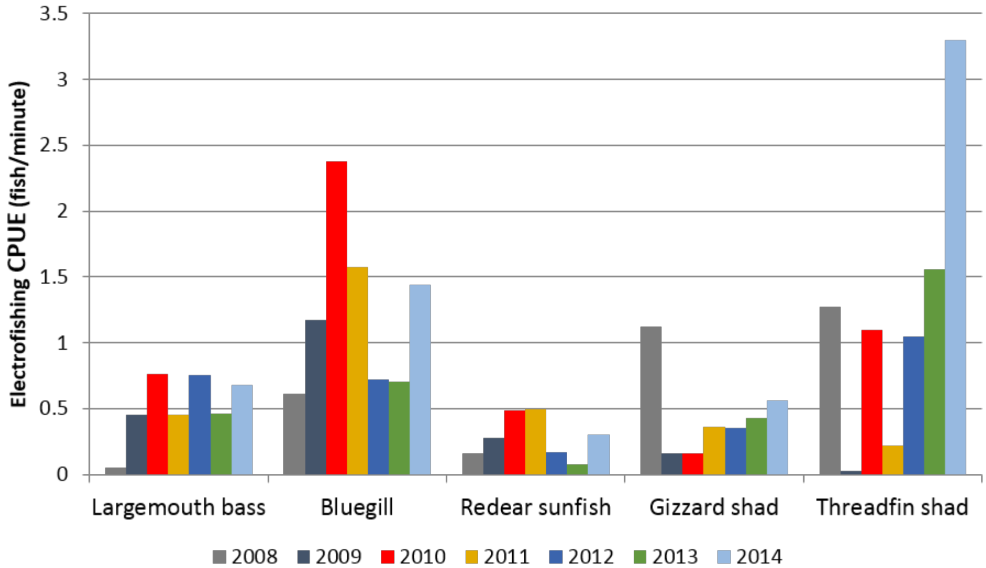


Figure 8-36. Electrofishing CPUE values for selected species collected October 2008–2014.

Trawling

Lake-wide trawl sampling at 27 pelagic sites during December 2014 resulted in the capture of 5,565 fish with a combined biomass of 419 kg. These were the second largest values for the total number of fish and biomass collected during the 10-year period from 2005 through 2014 (**Figure 8-37**). Eighteen fish species were represented in the catch. Five dominant species collectively comprised 94 percent of the catch by number and were, in order of abundance: threadfin shad, black crappie (*Pomoxis nigromaculatus*), bluegill, gizzard shad, and white catfish (*Ameiurus catus*). Seven dominant species collectively comprised 96 percent of the catch by weight and were, in order of biomass: white catfish, black crappie, bluegill, Florida gar, gizzard shad, channel catfish (*Ictalurus punctatus*), and threadfin shad.

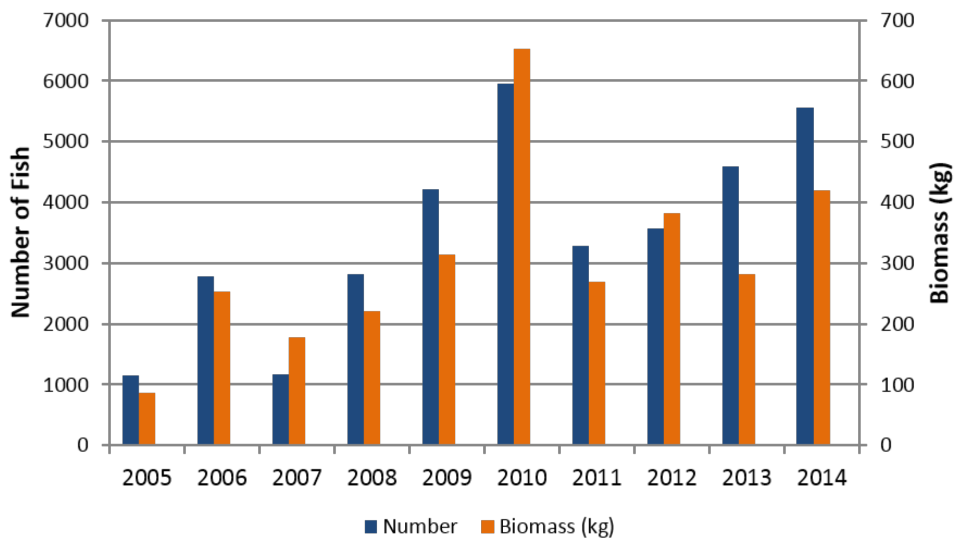


Figure 8-37. Comparison of lake-wide trawling data indicating the total number of fish (blue) and total biomass (orange) collected during December 2008–2014.

Black crappie comprised less than 5 percent of the pelagic catch from 2008 through 2010. However, concurrent with improvements in water quality and increased prey availability, mostly threadfin shad and black crappie abundance increased and accounted for 19 to 38 percent of the total catch in 2012, 2013, and 2014 (**Figure 8-38**). During the same three-year period, bluegill accounted for 13 to 24 percent of the total catch and white catfish comprised 9 to 15 percent of the catch (**Figure 8-38**).

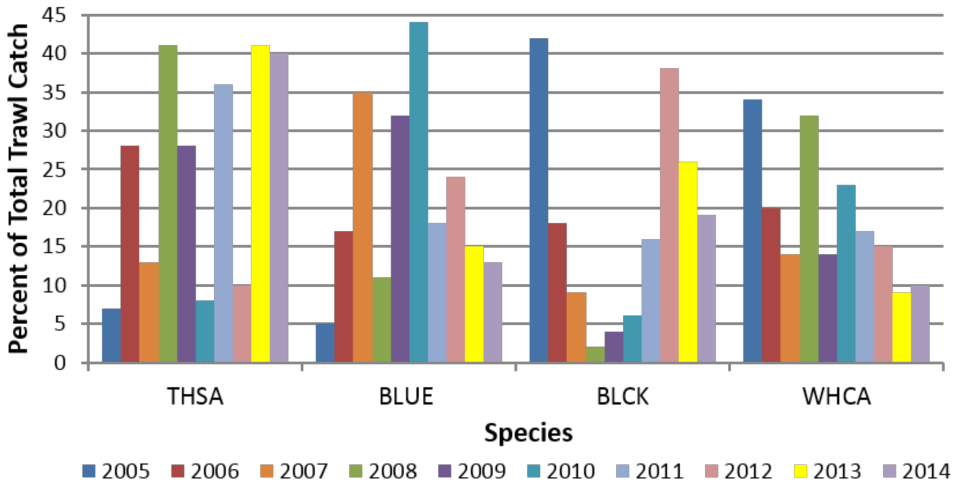


Figure 8-38. Percent of total catch of selected prey and piscivorous species collected by trawling in the pelagic region of the lake during December 2008–2014.

Selected Sportfish

The 2014 catch rate of 0.68 largemouth bass per minute was the third highest catch rate reported since 2005 and was more than twelve times greater than the lowest catch rate reported in 2008. In addition to an increase in largemouth abundance, the bi-modal size class peaks (8 to 18 cm and 24 to 36 cm) indicate that recruitment has occurred for a number of years and the population currently consists of a relatively large group of subadult (< 25 cm) and adult fish (**Figure 8-39**).

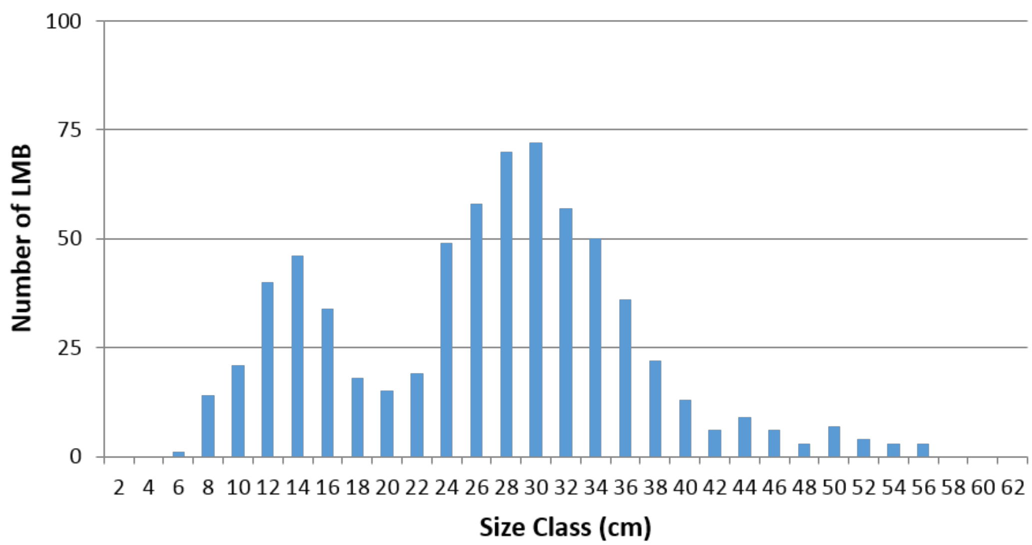


Figure 8-39. Length distribution per 2-cm size class for LMB (n = 676) collected by electrofishing at 22 nearshore sites in October 2014.

A total of 1,062 black crappie was collected by trawl from 27 pelagic sites in 2014. The catch rate of 1.97fish per minute was the third largest value reported during the period from 2005 through 2014 (**Figure 8-40**). Twenty-two percent of the black crappie were adult fish (≥ 20 cm) and the remainder were subadults (**Figure 8-41**). Having such a high number of smaller black crappie is a positive indicator for the population and suggests that the black crappie population is continuing to recover.

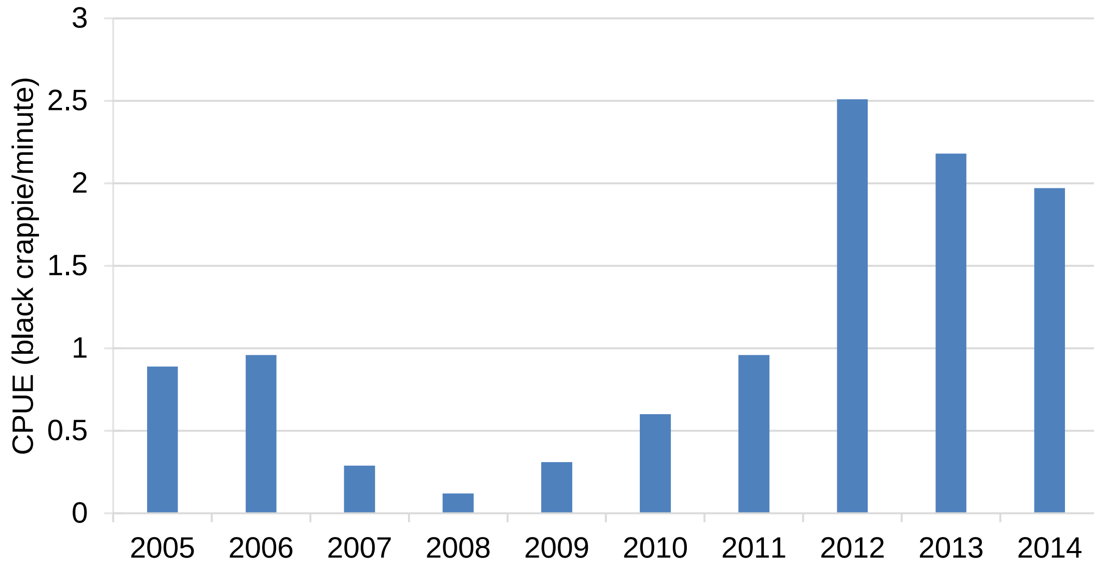


Figure 8-40. Catch rate (number of fish per minute) for black crappie collected by trawl from 27 pelagic sites during December 2008–2014.

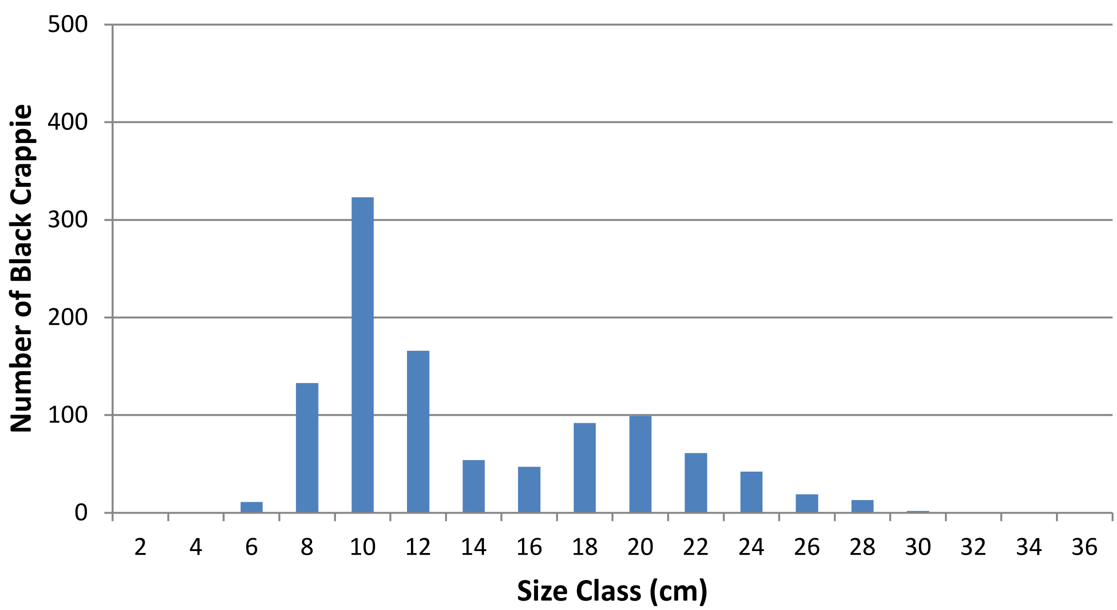


Figure 8-41. Length distribution per 2-cm size class for black crappie (n = 1,062) collected in December 2014 lake-wide trawl samples.

AVIAN MONITORING

Wading Bird Surveys

Wading bird foraging has been monitored in Lake Okeechobee since 2010. These data can be used as indicators of habitat quality and provide an important tool for examining the effects of hydrology, restoration efforts, and changes in the trophic levels that constitute the prey base. This monitoring can provide insight into habitat suitability and utilization based on climatology and water management decisions and allows for a general overall assessment of ecological conditions within the lake. It also provides important supporting data for the annual Lake Okeechobee wading bird nesting surveys carried out by Florida Atlantic University for RECOVER (www.evergladesrestoration.gov).

Methods

Wading bird surveys were conducted every two weeks via helicopter from December 2014 through June 2015 along east-west transects established at 2 kilometer (km) intervals throughout the entire littoral zone of Lake Okeechobee. Survey frequency was increased to biweekly starting in March 2013. Further details regarding survey methods are described in the 2012 SFER – Volume I, Chapter 8 (Zhang and Sharfstein 2012).

Foraging

In WY2015, lake levels during the survey season started at 15.58 ft NGVD29 on December 1, 2014, considerably higher (0.83 ft higher) than the average stage of 14.75 ft recorded for that date (**Figure 8-42**). This higher lake stage coincided with the lowest wading bird foraging numbers (169 birds on December 4, 2014) since surveys were initiated in 2010. After this initial high water period, levels receded by 0.92 ft from mid-March to mid-April, creating more suitable foraging conditions and establishing conditions for peak nesting on the lake. A reversal of approximately 0.2 ft occurred in late April at which time, the foraging survey conducted on April 30 identified only eight white ibis (*Eudocimus albus*) foraging on the lake. At that time, many wading birds were seen foraging outside of the lake primarily in canals and flooded fields in the EAA.

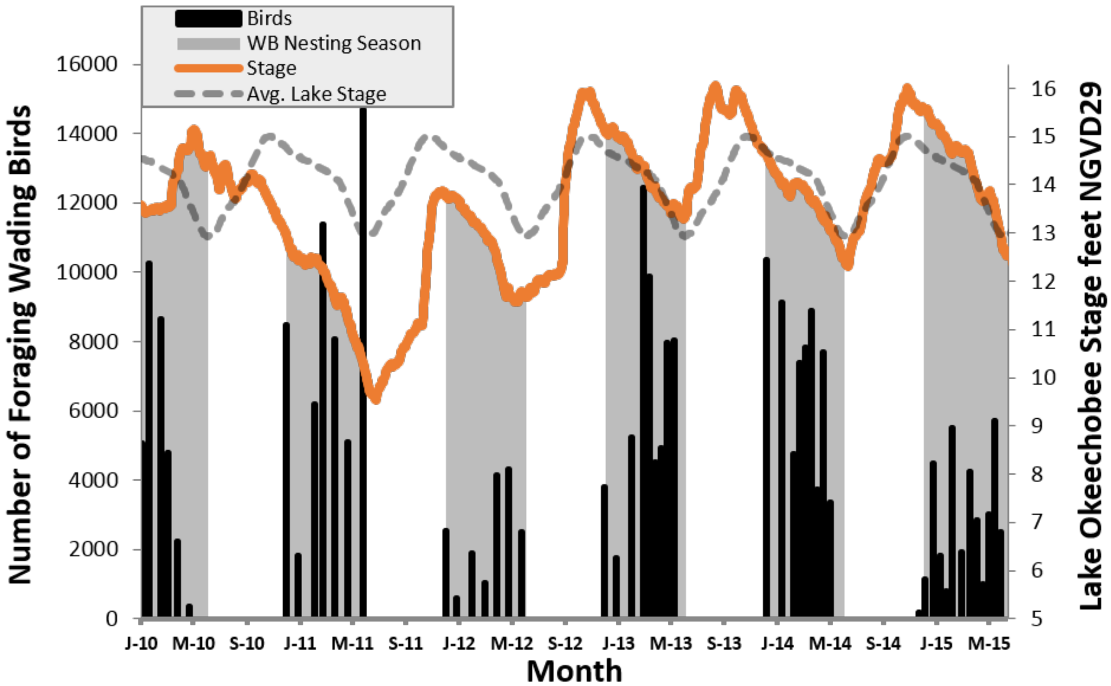


Figure 8-42. Number of foraging wading birds based on monthly surveys conducted on Lake Okeechobee from 2010 through 2015. Gray areas indicate the wading bird nesting season. The red line is the actual stage hydrograph while the gray dashed line represents the idealized, ecologically preferred hydrograph.

Nesting

Nesting effort data for wading birds on Lake Okeechobee are collected by Florida Atlantic University as part of the RECOVER baseline monitoring program. The small number of foraging birds in 2015, relative to the last two years, which had similar hydrologic parameters but many more birds foraging on the lake, did not translate into a below average nesting effort (**Figure 8-43**). This suggests that foraging conditions outside of the lake may have been better suited for wading birds and that these areas were selectively used relative to the Lake Okeechobee marsh even though water levels and recession rates also indicated suitable conditions on the lake.

A total of 4,615 nests [great egret (*Ardea alba*), snowy egret (*Egretta thula*), great blue heron (*Ardea herodias*), white ibis, tricolored heron (*Egretta tricolor*), little blue heron (*Egretta caerulea*), and glossy ibis (*Plegadis falcinellus*)] were estimated from monthly aerial surveys taken from March to May. Eight colonies were active (two of which are not directly on the lake), including the Liberty Point Two Colony, which produced over 60 percent of the total nesting effort including over 90 percent of the white ibis nests.

Since 2009, wading bird nesting on the lake has been fairly constant with average yearly numbers of 4,768 nests, ranging from 3,457 nests in 2014 to 9,185 nests in 2009. Environmental conditions contributing to this relatively stable nesting history may include the absence of large storm events, high prey production within the littoral zone, and an increase in woody nesting substrate.

For the first time since 1874 (an anecdotal report), a roseate spoonbill has successfully nested on Lake Okeechobee (personal communication, D. Essian, Florida Atlantic University). Through ground visits, Florida Atlantic University confirmed a nest with three fledglings on Little Bear Beach. Roseate spoonbills regularly use the lake as foraging grounds and have attempted to nest in

2009, 2012, and 2013, but according to available data this was the first successful attempt in the recent past.

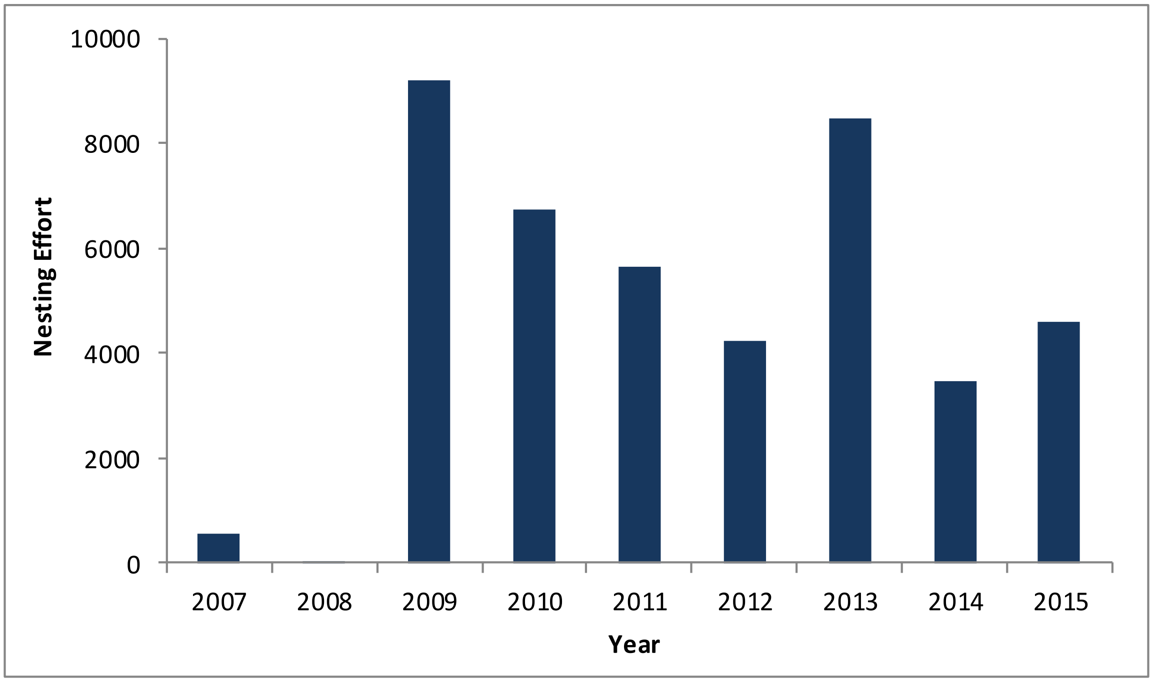


Figure 8-43. A comparison of nesting effort from 2007 until 2015. Total number of nests include seven species: great egret, snowy egret, great blue heron, white ibis, tricolored heron, little blue heron, and glossy ibis.

Lake Okeechobee Secretive Marsh Bird Monitoring

Emergent wetlands have declined precipitously in the past century (Tiner 1984), and the many species of birds that rely on these wetlands for their survival appear to be declining as well (Tate 1986, Conway 2008). Secretive marsh birds, such as bitterns and rails, which tend to be solitary and difficult to detect, are of heightened conservation status at the local and regional level as a direct result of habitat loss. The need to monitor populations of these birds is critical to effective conservation and management.

Lake Okeechobee has extensive suitable habitat to sustain a secretive marsh bird population, but the current status of the overwintering and breeding population is unknown. The paucity of data on population status and trends has led to very little consideration for management of this group of species. Resource management plans that focus only on wading birds may not support other obligate wetland species. For example, whereas wading birds require sparsely vegetated areas for foraging, secretive marsh birds require dense vegetation such as cattail for foraging and nesting, thus removal of dense emergent vegetation reduces habitat for these bird species. This is important information for Lake Okeechobee since current vegetation management plans primarily focus on creating open marsh habitat, whereas a habitat management plan that considers all native wetland avifauna might call for the maintenance of a mosaic of sparse and dense emergent habitats to support a greater diversity of bird species, and the avoidance of vegetation removal during critical breeding periods.

Therefore, the District has begun monitoring the secretive marsh bird population of Lake Okeechobee. Specific goals of this effort include (1) establishing baseline estimates of overwintering individuals and breeding pairs, (2) developing habitat and hydrologic management approaches to benefit marsh birds, (3) evaluating the impacts of habitat restoration success and assessing wetland ecosystem quality and, (4) assessing the potential impacts of invasive species on marsh birds [e.g., Burmese pythons (*Python bivittatus*) and other predatory species].

Methods

Call-response point count surveys are conducted in November and January for overwintering birds and in March and April for breeding birds. One round of surveys is conducted each month for overwintering birds and then one round for each survey period during the breeding season; March 15–31, April 1–14, and April 15–30. At least three surveys are needed to confirm seasonal presence/absence of some marsh bird species in a wetland with 90 percent certainty (Gibbs and Melvin, 1993).

Four survey transects consisting of 10 survey points each have been established throughout the littoral zone (**Figure 8-44**). Survey points along each route are 400-m apart to avoid the risk of double counting individual birds and to increase the total area covered by monitoring efforts. Target species include king rail (*Rallus elegans*), Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), American bittern (*Botaurus lentiginosus*), least bittern (*Ixobrychus exilis*), purple gallinule (*Porphyrio martinicus*), pied-billed grebe (*Podilymbus podiceps*), limpkin (*Aramus guarauna*), American coot (*Fulica americana*), common gallinule (*Gallinula galeata*), black rail (*Laterallus jamaicensis*), yellow rail (*Coturnicops noveboracensis*), and an exotic species, purple swamphen (*Porphyrio* sp.). Habitat characterization includes quantifying the percent coverage by wetland plants and major vegetation surrounding each survey point each year, which helps identify the causes of observed changes in marsh bird populations and the habitat preferences of each species.

Results and Discussion

Surveys for overwintering and breeding marsh birds were completed in 2015 and are planned to continue for one more season in 2016. Preliminary results from the breeding season surveys have been examined and are discussed in this section. One of the most abundant marsh birds in South Florida, the common gallinule, was also the most common bird detected in the survey (**Figure 8-44**). Two species, whose populations have been steadily declining (Sauer et al. 2014), the purple gallinule and the least bittern, were the next most abundant birds, respectively. The Torrey Island transect showed the highest abundance for all three of these species but also contained the highest abundance of the exotic purple swamphen. In contrast, no purple swamphens were found on the Cody's Cove transect although this species has been observed in close proximity to this transect. Two species, the king rail and least bittern were noticeably absent on the Cody's Cove transect as well even though confirmed breeding has been observed on the lake (personal observation, M. Baranski, SFWMD). It is assumed that higher than average water levels (50 to 120 cm) along this transect made the habitat unsuitable for king rail and least bittern breeding since preferred depths are 25 cm and 2 to 3 cm, respectively (Richmond et al. 2010, Rabe 2001).

Overall abundance data estimated for the entire lake identified the common gallinule as the most common secretive marsh bird species followed by the purple gallinule, least bittern, purple swamp hen, limpkin, and pied-bill grebe, respectively. It is possible that Lake Okeechobee may be a stronghold for the purple gallinule based on the high detection rates. Therefore, understanding habitat preferences for this species and adapting management activities accordingly could be a key factor in reversing its downward population trend. To gather accurate baseline data and density estimates for all marsh bird species utilizing the lake, transects may be moved or new ones created based on water levels at the time of the next survey to increase the probability of detecting king rails and black rails.

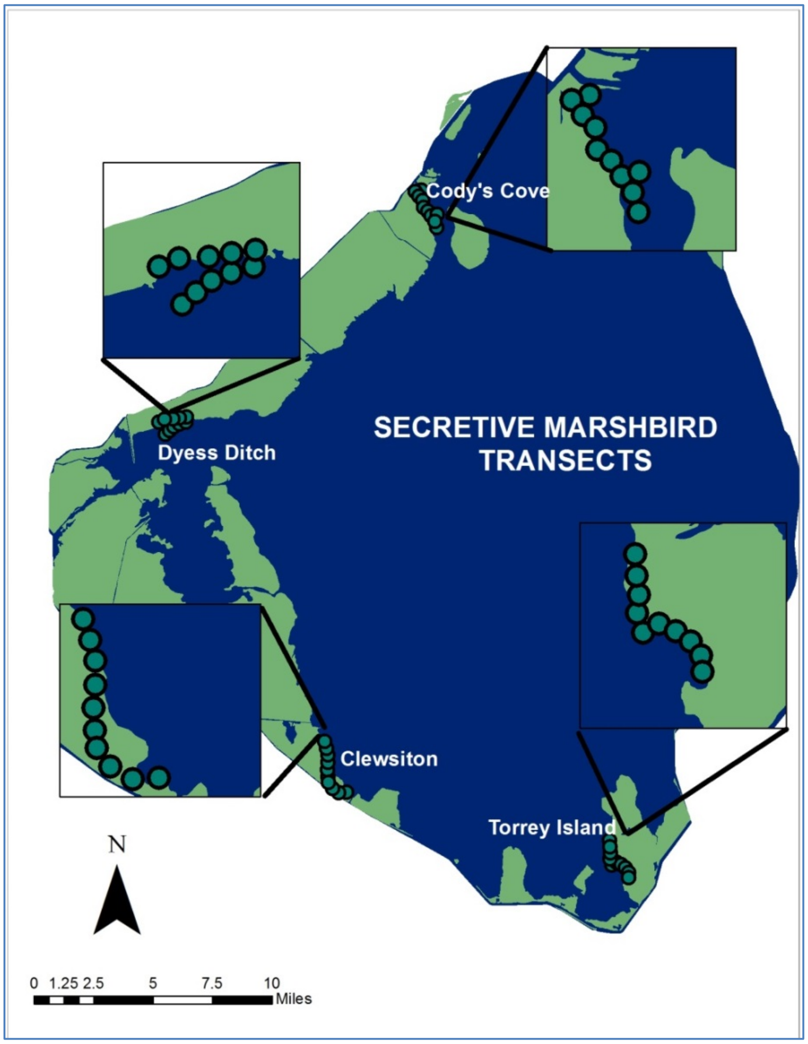


Figure 8-44. Location of the four marsh bird sampling transects used in 2015.

When sampling commences in 2016, marsh bird densities based on detection probabilities will be estimated using Distance software (Thomas et al 2010). These densities when combined with their associated habitat characterization will provide information on each species preferred breeding habitat; including hydrology and vegetation type and density. Estimated marsh bird densities can be compared to surrounding wetlands that have been surveyed in the North American Marsh Bird Monitoring Databasehttp://ag.arizona.edu/research/azfwru/NationalMarshBird/index.htm) as an indication of how much quality habitat exists for marsh birds on Lake Okeechobee. The same process will be utilized to estimate density and preferred habitat for wintering species.

Analysis of White Ibis Chick Diets in Lake Okeechobee

Wading birds are connected to hydrology through several aspects of their life history including nesting effort and success. Prey availability and foraging selection can also be influenced by variations in water management. Wading bird nesting success is necessarily related to the abundance and availability of different types of prey during the chick-rearing stages of the nesting season. Documenting diet composition and dietary responses to environmental variation yields important knowledge about patterns in resource use and impacts on resource management (Smith 1997). Dorn et al. (2011) suggest white ibis in the Greater Everglades will switch prey preferences according to changing water depths. Crayfish were preferred when levels were relatively higher and use of fish increased under drier conditions when the wetlands around the colony were simultaneously shallower and reduced in area. Understanding which prey species are critical to wading bird reproductive success is essential to effective management and restoration strategies. Fluctuating lake levels caused by management actions as well as natural occurrences can have substantial effects on nesting effort and success of wading birds on the lake.

The objectives of this project are to provide a quantitative assessment of white ibis diet composition in Lake Okeechobee and characterize the response of prey base and white ibis prey preference to changing hydrologic conditions during the breeding season by collecting and analyzing bolus samples. During the 2015 wading bird nesting season, the District collected 62 white ibis boluses in a three-week period from chicks ranging in age from 10 to 30 days at the Liberty Point colony in the southwest portion of the Lake Okeechobee littoral zone. Samples from the first season's collection will be processed and analyzed during the next several months. This project is planned to continue through the 2016 breeding season and become part of a collaboration with Florida Atlantic University where studies quantifying the available wading bird prey base and a diet study of breeding herons and egrets are being conducted concurrently.

FOOD WEBS IN LITTORAL MARSH PLANT COMMUNITIES

As a result of nearly seven years (2007–2013) of lake stages being mostly in or below the preferred stage envelope (12.5–15.5 ft NGVD29), EAV has expanded into former SAV habitat at a number of locations in the western nearshore region and in Fisheating Bay. The stable environment has also resulted in increased periphyton productivity, which may be translating into increases in higher trophic level consumer populations such as macroinvertebrates and fish. However, despite the apparent increase in littoral marsh habitat and its probable long-term persistence if the lake operating schedule does not change, relatively little data have been collected regarding littoral food web trophic dynamics. Of particular interest is how EAV communities dominated by *Sagittaria* sp., smartweed (*Polygonum* sp.), and water lily (*Nymphaea* sp.) contribute to the overall littoral trophic structure since these communities appear to be prime foraging habitat for Lake Okeechobee's breeding wading bird populations (**Figure 8-45**). The primary questions to be answered are (1) what type of habitat utilization is occurring in these important plant communities, and (2) are the food webs similar or different among the three vegetation types.

Sampling Regime

Throw trap sampling was conducted between February and June 2014 and 2015 for the following attributes: water quality, fish, macroinvertebrates, periphyton, phytoplankton, and zooplankton using techniques similar to those used in previous work evaluating the trophic structure of torpedograss and spikerush communities (Rodusky et al. 2013).

Biotic sampling was conducted within a throw trap, tossed haphazardly at four random locations in each of three dominant macrophyte habitats within the foraging range (< 5 km) of a littoral marsh wading bird colony, located in the western littoral marsh of Lake Okeechobee. Initial plans were to monitor each variable and biotic component at each site on a monthly basis for a year, but water depths from August 2014 through January 2015 were too deep to collect fish and macroinvertebrate samples via throw trap.

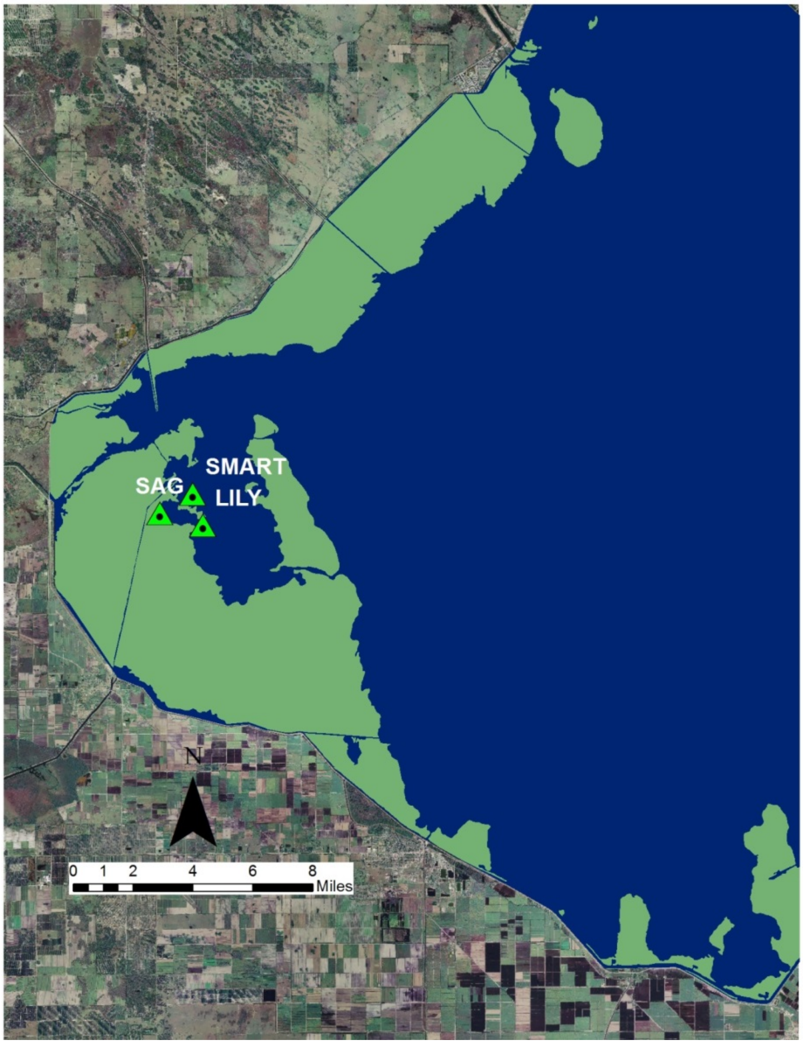


Figure 8-45. Location of the three western marsh littoral habitats: *Sagittaria* sp. (SAG), *Polygonum* sp. (SMART) and *Nymphaea* sp. (LILY).

Results

Preliminary results from this study indicate the following:

- Dissolved oxygen concentrations are generally very low in all three of these EAV communities.
- *Polygonum* communities generally had the lowest plant densities, while *Nymphaea* and *Sagittaria* communities had similar higher densities.
- All three communities appear to be dominated by fish rather than by macroinvertebrates with the *Polygonum* community having the highest fish densities relative to the *Nymphaea* and *Sagittaria* communities.
- The most abundant fish taxa in all three communities were eastern mosquitofish and least killifish (*Heterandia formosa*). However, overall species composition data for the three habitats has not yet been analyzed.

- Epiphyton, whether measured as ash free dry matter or biovolume was always highest in the *Polygonum* habitat.
- Phytoplankton densities were generally higher in *Sagittaria* and lowest in *Polygonum* and *Nymphaea*.
- Conversely, zooplankton densities were generally higher in *Polygonum* relative to *Nymphaea* and *Sagittaria*.

Overall, these preliminary data analyses suggest that *Polygonum* may provide better habitat for fish, macroinvertebrates, periphyton, and zooplankton than either *Nymphaea* or *Sagittaria*, although the disappearance of *Polygonum* habitat prior to and during the 2015 sampling period does not lend strong support to this theory because of *Polygonum*'s possibly ephemeral nature. Until the remaining samples are processed, no substantive ecological conclusions can be expressed about potential differences in the food webs in these three habitats. This study remains a work in progress and more details are expected to be available in the next water year and reported in the 2017 SFER.

VEGETATION DECOMPOSITION AND NUTRIENT RECYCLING STUDY

Major differences in nutrient cycling occur in Lake Okeechobee at low versus high water levels (James and Havens 2005). Periodically, there is a rapid increase of water level of the lake. Increased waves and turbulence associated with increasing water levels uproot and tear emergent vegetation leading to significant amounts of fresh litter. As this fresh litter decomposes, the nutrients are likely introduced to the water column contributing to increased nutrient concentrations observed at higher water levels.

To understand how plant decomposition is affected by such rapid water increases and how this decomposition contributes to nutrient dynamics under high water conditions, a standard method to measure fresh plant decomposition under both wet and dry conditions was tested. Litterbags (mesh bags filled with approximately 10 grams of plant material) of cattail or bulrush (*Schoenoplectus spp.*) were placed in dry or wet (submerged) locations within the lake. Three litterbags of each plant at each location were retrieved at six time points over the course of 120 days. The material was removed from the bags, dried in a 60 degrees Celsius oven to a constant weight, and ground and analyzed for nitrogen, phosphorus, and carbon. Based on the dried weights over time and the nutrient content, estimates of the change in nutrient mass over time could be determined.

These preliminary data suggest that similar to the dry weight reductions (as reported in the 2015 SFER – Volume I, Appendix 8-1; Sharfstein et al., 2015) there is a more rapid removal of nutrients under wet conditions than dry (**Figure 8-46**). This is defined by the differences in the intercept estimates for carbon and nitrogen (**Figures 8-46**, panels A through D). The change is more pronounced for phosphorus (**Figure 8-46**, panels E and F), with a rapid reduction in the first two weeks followed by a much slower rate thereafter. These results are consistent with those of Chimney and Pietro (2006) who also found rapid loss of nutrients in wet cattail litter bags as compared to those left in the air on a pole to simulate decomposition of standing dead cattail.

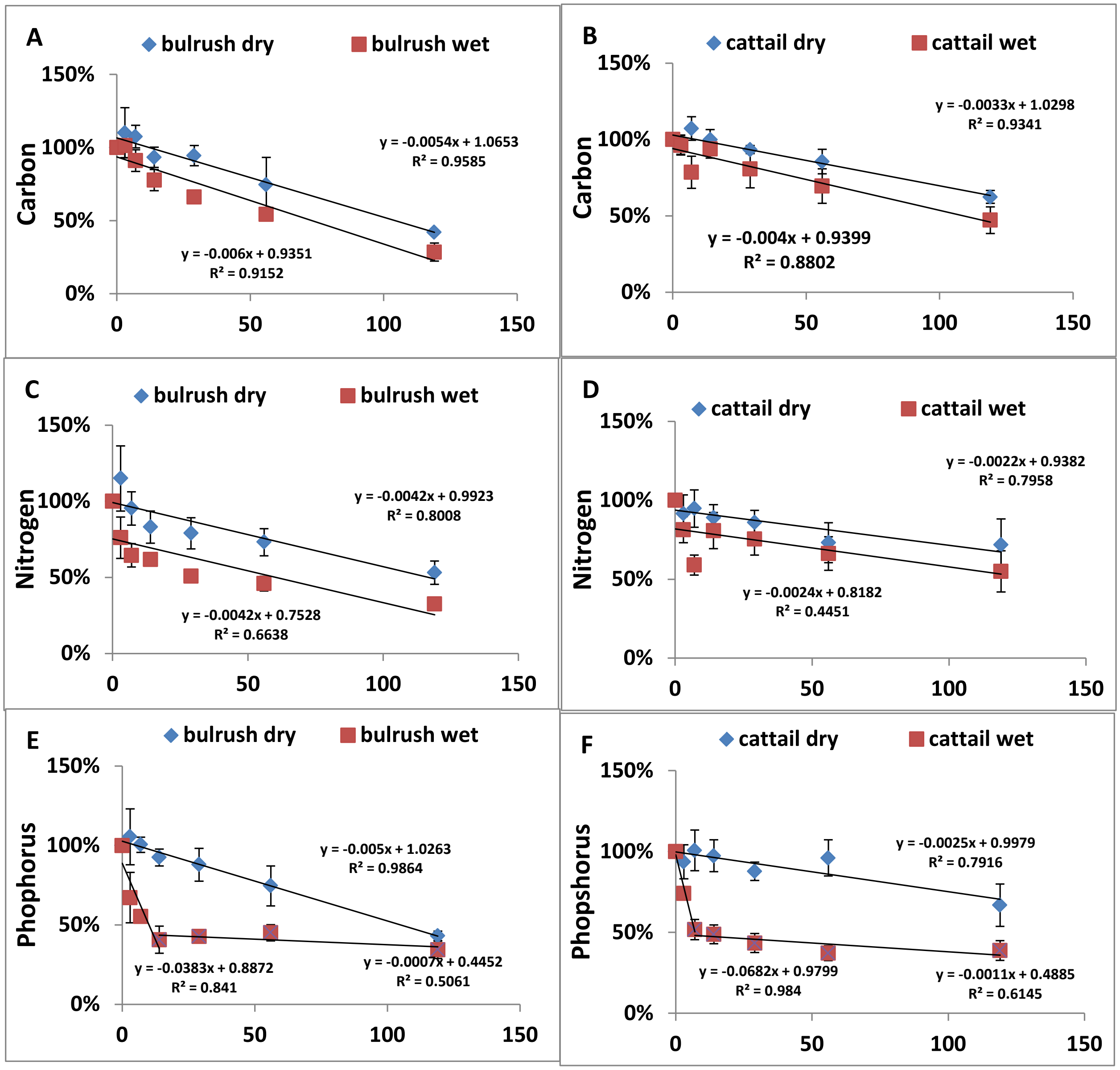


Figure 8-46. (A) Bulrush and (B) cattail percent carbon remaining over time, (C) bulrush and (D) cattail percent nitrogen remaining, and (E) bulrush and (F) cattail phosphorus remaining for litterbags in wet or dry conditions. Lines are linear regressions of the data. Error bars are 1 standard deviation.

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